POWER PLANT ENGINEERING

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Announcing

Two Issues In One

IN ORDER TO SERVE its readers and advertisers more advantageously, in conformity with the general economic and industrial trends, POWER PLANT ENGINEERING will consolidate its semi-monthly issues in one issue on the first of the month beginning with September.

Editorial strength and quality will be maintained by the same staff that has heretofore kept readers informed on design, construction, operation and modernization of power plants and power using equipment. Articles will be more condensed to save time and further the convenience of readers but the field will be as comprehensively and satisfactorily covered as before.

Exclusive articles on important engineering achievements, special articles on plant operation and staff articles on latest methods and trends will continue to be helpful features, essential to the up-to-date power executive.

Subscribers will receive the full number of issues paid for. Moreover, they can confidently rely on POWER PLANT ENGINEERING'S editorial staff to continue to make it the outstanding publication serving the field and the most useful companion obtainable to assist them in their management of the country's important power and manufacturing plants.

WITH THE EDITORS

Simpler Distribution of Goods

ONE ITEM WHICH frequently adds to the cost of goods to the consumer so much as materially to reduce the possible market is too high cost for selling and distribution. For many kinds of farm produce, for raw materials and for some manufactures, this item is much larger than the cost of production. Such a condition limits the ability and the inclination of possible consumers to buy as much as they would like and could well use.

Excessive selling and distribution costs arise from lack of direct paths from producer to consumer and from competition gone wild. For most products there is a natural market that can be profitably supplied. If high-pressure selling is used to force sales beyond that point, the cost of selling and distribution is greatly increased.

Central station supply of energy to its natural territory is an excellent example of well planned selling and distribution, though, in some instances, high-pressure selling has been exerted to secure industrial plant business that should not have gone on the utility circuits. Distribution is, however, direct as possible from producer to consumer, sales are according to the consumer's needs, duplication of selling effort and distributing systems are avoided and the temptation to expensive competitive selling effort or to profitless price cutting is eliminated.

That regulated monopolistic conditions would be effective in all lines of industry is by no means certain. It would surely be contrary to the theory of unlimited competition on which our anti-combination laws are based. But, some form of coöperative action in industry, possibly through supervised trade associations, by which the economical supply of the needs of consumers under conditions which will yield fair return on capital and steadier employment to workers would seem possible, without destroying the incentive to individual initiative and enterprise.

The important thing is to get the cost of goods down so that they can be sold at a price that will attract buyers yet yield a profit. Into the problem enter effective use of power, of machinery, of labor, of capital, effective sales methods, economical distribution, satisfaction to buyers.

Future Power

NEED FOR ADEQUATE cooling of internal combustion engines has been recognized since the earliest days of their operation. Early Diesel design used effective piston and valve cooling by water and oil and these applications are now finding their way into the gasoline engine field heralded as the next big advance necessary to use modern anti-knock fuels adequately and efficiently.

Tests made by the Ethyl Gasoline Corp. are of value in showing the need for adequate cooling in order to obtain full engine output and satisfactory efficiency. A single cylinder, high-compression, 3¼ by 5-in. experimental engine was used for the tests with the compression ratio adjusted so that only part load could be carried without detonation. Later, the addition of a water-cooled valve permitted an increased output of 8 per cent. Use of soapsuds as a crank case lubricant with a copious spray on the underside of the piston increased the output 25 per cent, while a combination of the two cooling methods increased the output one-third. Then tests were made with the same fuel and a 15 to 1 air-fuel mixture.

Increases in output are less pronounced with richer mixtures, indicating that the need for adequate cooling is greater in engines designed for economical operation. As always, increased efficiency is dependent upon increased complications which often nullify the advantages of higher efficiency. The world awaits something new in the field of power, something simple but efficient. Water, steam and Diesel equipment have been developed to the point where further increases in efficiency are incremental. What is needed is a new system which will double or triple the efficiency of the steam and Diesel cycle.

Power for Farm and Fireside

IN THE GOOD old days before General DePression took command of the industrial army, when factories were busy, motor load was heavy and increasing and central stations could hardly be enlarged fast enough to keep up with demand, domestic consumers and rural customers were mostly considered as fringe load with possibility of increase in due time but not of major consequence.

Now, with 20,000,000 homes using electricity to almost as great an extent as ever and the farm users increasing in 1931 until 700,000 farms were connected, with the number still increasing, these two classes of load are proving the backlog that preserves the central-station prosperity flame. Domestic consumption of current has increased because of larger use of ranges, refrigerators and the like, while farms served increased in number 7.5 per cent during 1931.

Fully electrified homes and farms will work changes in the house and on the farm similar to those which followed the introduction of steam power in factories except that, since power can easily be taken to the job, concentration of workers will be unnecessary.

Since the farm and fireside have proved so dependable and have such large possibilities for using more power, it would seem the part of wisdom to give them the attention due to a major factor in the prosperity of the central station industry. Promotional campaigns, development of equipment to the highest point of reliability and economy, working out rate structures to encourage wider and larger use of current by domestic and rural customers would seem to be profitable lines of activity.

Suggestions for Profitable Reading

A Real High Pressure Argument

Do you recall how, a few years ago, when you first saw the 4-inch thick forged steel drum of a 1200 lb. pressure boiler, you blinked, rubbed your eyes and looked at the thing again to make sure you weren't dreaming? True, outwardly, you may have retained your composure by pulling off a wise crack about Big Bertha or something of that nature, but in your own mind you knew the designers were all cuckoo, that the thing would never work and that if that cylinder was part of a boiler you were an Eskimo. Well, when the boiler was placed in operation later on, you probably revised your opinions about its working but still you were skeptical as to the cost of operating such units. They seemed terribly expensive. Steel drums four inches thick you argued had their proper place in the shape of heavy artillery with ample Army and Navy appropriations behind them, but to use such things around a boiler plant—well, that was absurd.

Lately we have all changed our minds about many things and while we are about it we may as well change our opinions about these high pressure boilers if we haven't already done this. Not only are they practical but they are reliable and inexpensive to operate. "Prove it," you say? Well, all right. Take the case of Lakeside in Milwaukee, for instance, one of the pioneer stations using high-pressure boilers. During 1931 the availability of the three 1290-lb. boilers was over 95 per cent and the total cost of repairs and maintenance, including shop labor and material, was only 18 cents per boiler hour. Outages? Scarcely enough to mention—an average of one boiler every four months!

Now that's a pretty good record, don't you think? It's about as perfect as one can expect from even low pressure heating boilers. Details of the 1290-lb. boiler plant at Lakeside are given by Mr. Post in tabular form in his article on page 564.

A Question of Degree

Temperature readings are easy to obtain. Thermometers are cheap and a few laid around the plant at strategic points will give you a whole flock of readings with which you can embellish even the most drab of log sheets. Indeed, quite often thermometers of any variety are superfluous so far as the log sheet is concerned, good guesses serving quite as well.

If, however, you really want to use temperature readings—if you need them in making calculations, neither guesses nor the common garden variety of temperature readings will do. For such purposes you need good thermometers and careful observations.

Correct temperature observations take time, care and experience. Consider just one instance, that of condenser operation. Condenser performance is an extremely important factor in plant economy and in order to know what your condenser is doing you have to know water temperatures to a tenth of a degree. Anybody that has ever tried to guess even a third of a degree in reading a thermometer will realize that this is no easy matter. Yet it is quite possible. At Long Beach Station in California they worked out an arrangement which does it to perfection and Mr. Woolley tells about it in this issue. It is reported that every morning when Mr. Woolley walks into the plant the condensers open their mouths, say "Ah-h-h-h", stick out their tongues and belch up a whole roll of temperature record sheets for inspection.

We're Not Through Yet

As we mentioned here some time ago, those who believed in 1920 that a 35,000-kw. generating unit was the largest that would be built have had occasion to alter their views in regard to station design many times. We have seen generating units grow to 165,000 and 208,000 kw. capacity Boiler units in the same time have attained outputs as high as 1,250,000 lb. of steam per hr. and pressures as high as 1200, 1800, even 3200 lb. per sq. in. We have seen rotating electrical power equipment placed out of doors, running in atmospheres of hydrogen and we have seen boilers and turbines operated with mercury instead of water. In every branch of the entire field of power plant engineering, development has been intensive and revolutionary. There is scarcely any piece of equipment in use today which has not been improved during the past twelve years.

In this issue Professor A. G. Christie of Johns-Hopkins University discusses modern central station performance. Those who have kept up with progress directly or through the medium of the technical publications will find much in Professor Christie's paper with which they are familiar, for his discussion is one which was submitted for presentation at the International Electrical Congress in Paris and its purpose is largely to present an account of American Power Plant development, but regardless of how well you know your power plant technique, you will find this article of value. If nothing more, it will serve to impress you with the remarkable performance of present day power generating equipment.

The record of accomplishment so far is a fine tribute to the skill and resourcefulness of the engineer, but the end is not yet. American central stations are still undergoing change. Higher operating pressures and temperatures are now recognized as practical and economically justified. The present effort aims towards the production of more kilowatt hours per dollar of total expense.

Photo. Ray Littleton, So. Bend

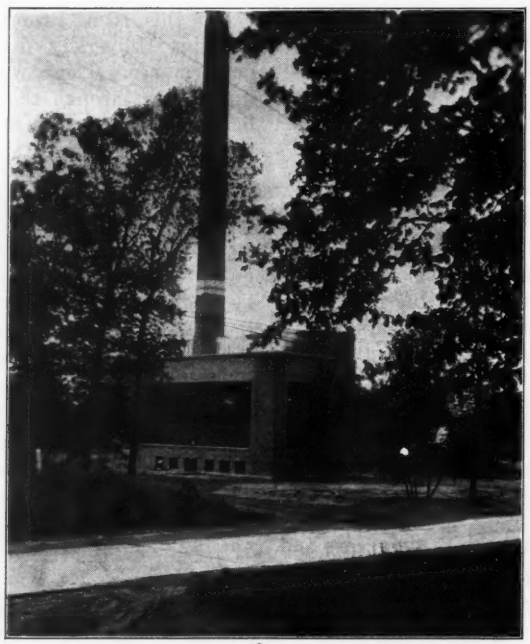
New Boiler Plant for NOTRE DAME UNIVERSITY

New $280,000 boiler plant with four 405 hp. forced-draft, stoker-fired boilers supplies heat and hot water to the university

FACED WITH THE NECESSITY of providing for 43,000 sq. ft. of additional radiation included in a $2,100,000 building program, the University of Notre Dame, South Bend, Indiana, in 1931 decided to build a new boiler plant rather than revamp the old one to carry the extra load.

This building program, now completed, includes an engineering building, a commerce building and two new dormitories, the first being made possible by a gift of John F. Cushing, '06, president of the Great-Lakes Dredge & Dock Co., Chicago, and the second by a gift of Edward N. Hurley, president of the Hurley Machine Co., Chicago, and head of the Shipping Board during the World War.

Total radiation on the campus is now 300,000 sq. ft. divided among the 47 buildings necessary to take care of the instruction, housing and feeding of the 3000 students. This requires 15,000 t. of coal a year, the steam requirements during the month of December, 1931, totaling 30,000,000 lb. During April, 1932, the first month the new plant carried the load the steam consumption was 21,331,193 lb. requiring 1408 t. of coal.



Some 30 yrs. service in a constantly growing university had, as early as 1930, pushed the old boiler plant to the limit of its capacity and near to the limit of its economic life. During the summer of 1930 a complete system of instruments and flow meters was installed and during the winter of 1930-31 a close study of the requirements was made by Bro. Irenaeus, C.S.C., in charge of heating and electricity at the university and by C. C. Wilcox of the Studebaker Corp.

New Plant a Practical Laboratory

As a result of this study and because of the future needs of the campus it was decided to build a new plant about 250 yd. to the northeast of the old plant where it would not be in the way of future development of the

campus. Furthermore, the new plant is near the lake with plenty of water, an adequate intake and sufficient building space to add a turbo generator and make the new plant a practical laboratory for the mechanical engineering students. The new plant, designed by Albert Kahn, Inc., is connected with the old by a tunnel.

On the main floor are the four boilers with the forced draft fans immediately behind each boiler and the boiler feed pumps in the middle of the building between the No. 2 and No. 3 boilers as shown by the longitudinal section. Above the boiler feed pumps are located the feedwater heaters and condensate return tank. In the basement are the Zeolite softener, domestic hotwater heaters, service water and fire pumps, vacuum return pumps and transformers.

Indiana coal, received by rail, is dumped either directly to the track hopper from a trestle to be stored out by a Sauerman drag scraper; or coal coming into the plant passes through a Stephens-Adamson crusher on to a pivoted bucket conveyor which runs the length of the basement and then up over the 800 t. coal bunker. Coal

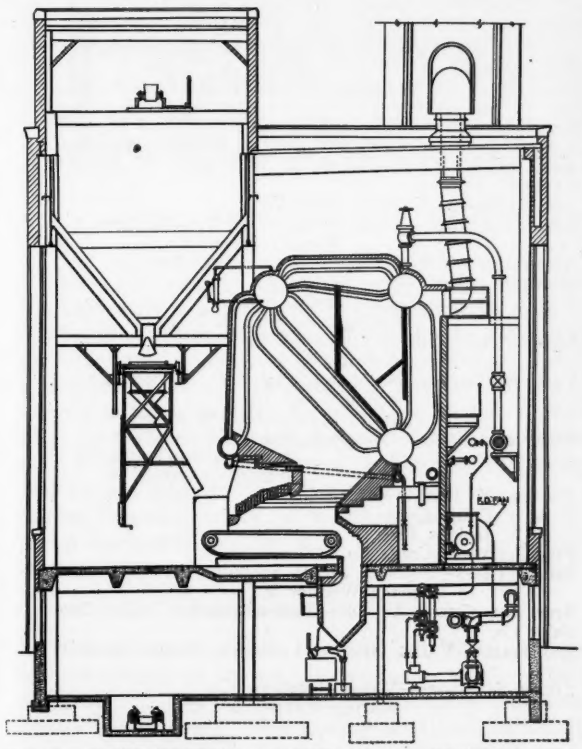


FIG. 3. CROSS SECTION OF THE PLANT SHOWING THE ARRANGEMENT OF THE EQUIPMENT AND BOILER SETTING

is weighed at each boiler by a weigh larry. Ash is handled from the Allen-Sherman-Hoff hoppers to the same pivoted bucket conveyor by Koppel industrial cars and is stored in a special bunker at one end of the plant.

Use Natural Draft to 150 Per Cent of Rating

The 405-hp. 200 lb. type NA Union boilers, with water cooled front walls, have 1423 cu. ft. Detrick air cooled furnaces designed for a maximum heat release of 31,300 B. t. u. per hr. per cu. ft. of furnace volume. Boilers are fired by 96 sq. ft. steam-engine-driven Laclede five compartment forced draft stokers with Hagan combustion control. One 150 ft. above the roof, 8 ft. 3 in., I. D. Custodis stack serves all four boilers. At loads up to 150 per cent of rating the boilers will be operated on natural draft.

Forced draft is supplied by individual Sturtevant fans rated at 15,000 c.f.m. at 3½ in. static pressure. Each fan is dual driven by a 15-hp. induction motor and

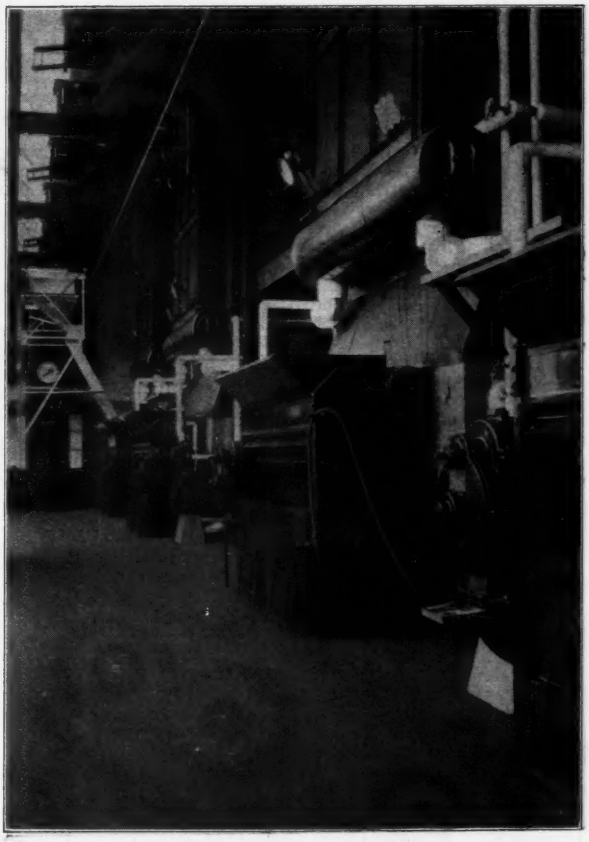


FIG. 2. THE FIRING AISLE. THE DRUM ABOVE THE STOKER HOPPER IS THE BOTTOM HEADER OF THE FRONT WATER WALL

a 13-hp. turbine. These fans are located immediately back of their respective boilers as shown by Fig. 3. Each boiler has a Hays boiler panel with a Hays 8 pointer draft gage, Ranarex CO_2 meter and Brown flow meter.

Return tank, feedwater heater and boiler feed pumps are located in the center section of the plant as shown in the drawing. The heater is a 100,000 lb. per hr. Cochrane metering deaerating type and is located directly above the three boiler feed pumps.

All Water From Lake

These pumps consist of one American 12 by 7 by 12 in. outside center packed horizontal duplex and two Dayton Dowd two stage centrifugals. One of the centrifugals is driven by a Westinghouse 50 hp., 3600 r.p.m. motor, the other by a 45-hp. Moore 3600 r.p.m. turbine. Each of the three pumps is rated at 200 gal. against a pressure of 160 lb. Control of all the electric auxiliaries is from a centralized panel board near the center of the firing aisle.

PRINCIPAL EQUIPMENT NOTRE DAME BOILER PLANT

GENERAL

ENG. AND ARCH.—Albert Kahn, Inc.
CONTRACTOR—Thomas Hickey
PIPING CONTRACTOR—Wm. Blaney
BOILER SETTINGS—Lyons & Long

BOILERS

BOILERS—Union Iron Works, 4, type NA 405 hp., 135 lb. operating pressure bent tube boilers, 16 tubes wide.
FURNACES—M. H. Detrick Co. with air cooled walls and arch. Volume 1423 cu. ft. for heat release of 31,300 B.t.u. epr hr.
STOKERS—Laclede Stoker Co. 4, chain grate forced draft stokers, 8 ft. wide, 96 sq. ft. of grate surface.
FORCED DRAFT FANS—B. F. Sturtevant Co. 4, each with a capacity of 15,000 c.f.m. of 75 to 225 deg. F. air against a static pressure of 3½ in. Each fan driven by a 15 hp., 1750 r.p.m., 220 v. General Electric induction motor and a 13 hp. 5 lb. back pressure Sturtevant turbine.
COAL AND ASH HANDLING EQUIPMENT—Stephens-Adamson Mfg. Co. 50 t. per hr. capacity.
DRAG SCRAPER—Sauerman Bros., Inc.
ASH CARS—Koppel Ind. Car & Equip. Co.
ASH HOPPERS AND GATES—Allen Sherman-Hoff Co.
BLOW-OFF VALVES—Yarnall Waring Co.
BOILER PANELS—Hays Corp.
BREECHING—Graver Tank & Mfg. Co.
CO_2 RECORDERS—Permutit Co.
COMBUSTION CONTROL—Hagan Corp.
DRAFT GAGES—Hays Corp.
FAN BEARINGS—Fafnir Bearing Co.
FEED WATER REGULATORS—Copes, Northern Equipment Co.
SAFETY VALVES—Consolidated Ashcroft Hancock Co.
STOKER DRIVE—E. H. Wachs Co.
SOOT CLEANERS—Vulcan Soot Cleaner Co. 6 elements per boiler.
STACK—Alphons Custodis Chimney Construction Co. 150 ft. high, 8 ft. 3 in. inside diameter on top
STEAM FLOW METERS—Brown Instrument Co.
WATER COLUMNS—Reliance Gauge Column Co.

HEATERS AND SOFTENER

WATER SOFTENER—Permutit Co. double unit Zeolite softener, maximum flow of 200 g.p.m., total capacity of 30,600 gal. of 14 grain per gal. water in 5.14 hr.
WATER METERS—Neptune Meter Co.
FEED WATER HEATER—Cochrane Corp., 100,000 lb. per hr., deaerating metering type.
WATER HEATERS—Whitlock Coil Pipe Co., 2—2,000 gal.
HEATER RELIEF VALVES—Crane Co.
TEMPERATURE REGULATORS—Powers Regulator Co.
THERMOMETERS—Taylor Instrument Cos.

PUMPS

BOILER FEED PUMP—Dayton Dowd Co. 2 type CSDX 2 in. centrifugal boiler feed pumps, each with a capacity of 200 g.p.m. at 165 lb. discharge pressure One driven by a Westinghouse 50 hp., 3600 r.p.m., 200 v. induction motor; the other by a Moore Steam Turbine Co., 45-hp., form UTR 3600 r.p.m. turbine exhausting at 5 lb. back pressure.
BOILER FEED PUMP—American Steam Pump Co., 1, 12 by 7 by 12 outside center packed horizontal duplex steam pump.
VACUUM PUMPS—American Steam Pump Co., 3, 10 by 14 by 20, horizontal simplex steam pumps with capacity of 100,000 sq. ft. of radiation each.
SERVICE WATER PUMPS—Allis Chalmers Mfg. Co. 2, 8 in. type S.I. centrifugal with a capacity of 1500 g.p.m. against a 282 ft. head. One pump driven with 135 hp. 2146 r.p.m. turbine and the other with the same type of turbine and a 100-hp. 1750 r.p.m. 220 v. induction motor.
FIRE PUMP—Worthington Pump & Machinery Corp., 16 by 9 by 12 horizontal duplex steam fire pump, capacity 750 g.p.m.
HOT WATER PUMPS—Worthington Pump & Mach. Corp., 1, 6 by 4 by 6 and 1, 7½ by 5¾ by 6, horizontal direct acting steam pumps.
HEATER DRAIN PUMP—American Steam Pump Co., 4 by 5 by 8 horizontal duplex steam pump.
RECEIVER PUMP—American Steam Pump Co. 7 by 6¾ by 8 horizontal duplex steam pump with receiver.
SUMP PUMPS—Nash Engineering Co., 2, with a capacity of 12 g.p.m. at 30 ft. head, driven by 3-hp. General Electric motors.

TRANSFORMERS AND MISCELLANEOUS

SWITCHES—Westinghouse Elec. & Mfg. Co. 3, 75 kv-a. power transformers and 1, 37½ kv-a. lighting transformer, both 4000/220 v.
DEAD FRONT PANEL BOARD—Westinghouse Elec. & Mfg. Co.
AIR COMPRESSOR—Gardner Denver Co. 4½ by 4 in. with a maximum capacity 64 c.f.m. at 90 lb. pressure, maximum speed of 725 r.p.m. Driven by a Wagner 10 hp. 220 v. motor.
AIR FILTER—A. C. Spark Plug Co.
LUBRICATING OIL TANKS—Tokheim Oil Tank & Pump Co.
Bennett Pumps Co.
ACETYLENE FOR WELDING—Linde Air Products Co.
MOTOR STARTERS—Cutler Hammer
Square D Co.
Westinghouse Elec. & Mfg. Co.
LUBRICATORS—Hills McCanna Co. on boiler
Manzel Bros. Co.
PRESSURE GAGES—Consolidated Ashcroft Hancock Co.
Federal Gauge Co.
Jas. P. Marsh—Gauges, Valves
PUMP AND ENGINE GOVERNOR—Fisher Governor Co.
Northern Equipment Co.
Waters Governor Co.
VALVES—H. Belfield Co.
Crane Co.
Jenkins Bros.
PIPE FITTINGS—Crane Co.
STEAM TRAPS—Boylston Steam Specialty Co.
Warren Webster & Co.
STOP AND CHECK VALVES—Golden-Anderson Valve Specialty Co.
ADJUSTABLE VALVE SPROCKETS—Babbit Steam Specialty Co.
STEAM STRAINERS—Mason Regulator Co.
Warren Webster & Co.

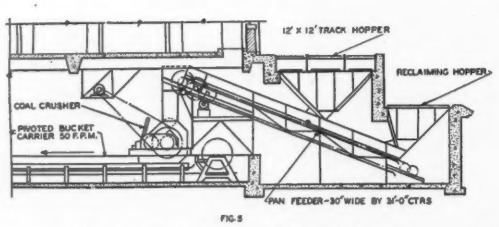


FIG. 5

FIG. 5. COAL HANDLING EQUIPMENT AND CRUSHER

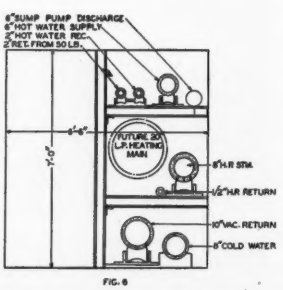


FIG. 6

FIG. 6. ARRANGEMENT OF PIPES IN THE TUNNEL

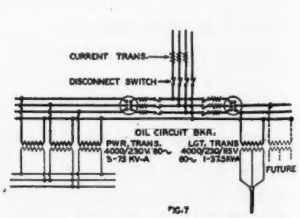


FIG. 7

FIG. 7. TRANSFORMER WIRING ARRANGEMENT

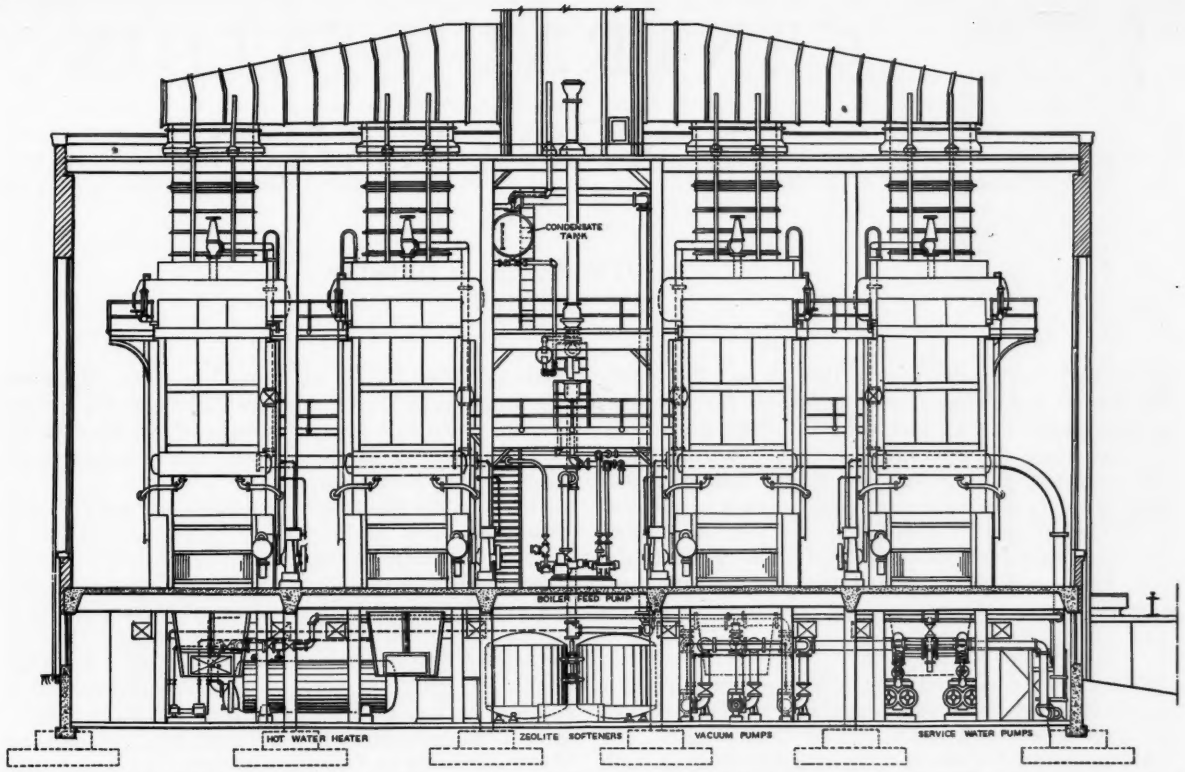


FIG. 4. LONGITUDINAL SECTION OF THE PLANT SHOWING THE AUXILIARIES LOCATED BETWEEN NOS. 2 AND 3 BOILERS

All water used by the plant and service water for the university is taken from the lake through a 24 in. intake. This water runs about 14 gr. to the gallon and the boiler feed is softened by a double Permutit Zeolite system rated at a total maximum flow of 200 g.p.m. Service water is pumped by two Allis Chalmers single stage centrifugals with a capacity of 1500 g.p.m. against a head of 282 ft. One of these is driven by a 135 hp. turbine, the other by the same type of turbine or by a 100-hp. induction motor. A Worthington 750 g.p.m. fire pump discharges into the same line for fire protection service.

Condensate Returns

Hot water is heated in two 2000 gal. Whitlock heaters and circulated around the campus by a 6 by 4 by 6 in. or by a 7½ by 5¾ by 6 in. Worthington horizontal duplex steam pump. The heating coils are drained by an American 4 by 5 by 8 in. horizontal duplex discharging to the condensate tank above the feedwater heater.

High pressure drips are collected by an American 7 by 6¾ by 8 in. receiver set and pumped to the same tank. Heating system returns are handled by three 10 by 14 by 20 in. American simplex steam vacuum pumps.

A new tunnel, shown in the drawing Fig. 6, connects the new plant with the old one and with the old low pressure distribution system. At present 135 lb. steam is supplied to the pressure reducing station at the old plant but space has been provided in the tunnel for a low pressure main direct from the new plant.

All power is purchased and is brought into the plant at 4000 v. to a bank of four 75 kv-a. 4000/220 v. power transformers as shown in the wiring sketch Fig. 7. The lighting supply is taken from one 37½ kv-a. single phase 4000/220 v. transformer with provision made for a second unit in the future.

At one end of the plant is the office of L. V. West, chief engineer, and at the other a small laboratory for carrying out the routine operating tests.

A Combined Electric Power and Steam Supply Station

An interesting station has recently been completed in Brunn, Czecho-Slovakia, by the Skoda Works Co. for the Western Moravia Electricity Works Co., the plant being adapted to supply steam as well as electrical energy to the various textile mills in the district. Steam is generated at a pressure of about 938 lb. per sq. in. in a battery of boilers capable of generating 200 t. of steam per hour. The generating plant comprises two 4500-kw. 6300 v. turbo-generators and one 9000 hp. set. The exhaust steam at about 128 lb. pressure is diverted into long distance distribution pipes and a 6000-kw. low-pressure turbo-generator set has also been installed to utilize any excess of steam not required for industrial purposes. Conversely, live steam can be passed to the distribution pipes through pressure reducing valves when the industrial demand increases at a time when the call for electric power supply is low.

The color of walls and ceilings plays an important part in the efficiency of a lighting system. Semi-indirect and totally indirect systems require white or very light ceilings and upper side walls down as low as the top of the windows.

CENTRAL STATION PERFORMANCE*

By A. G. Christie**

RECENT turbines for 450 to 1200 lb. and 700 to 825 deg. F. are bled at one to five points for regenerative feedwater heating and, for 600 to 1200 lb., usually have one stage of reheating. Flue gas reheating gives higher station economy but live steam reheaters suffice where the only object is to decrease moisture at exhaust.

Storage of coal in silos and in outdoor piles shows a trend toward elimination of coal bunkers inside the boiler room, with reduction of station cost and improvement in boiler room lighting.

Steam Generation

Use of single-pass boilers is increasing since they cost less, permit simpler boiler plant, carry higher ratings and have lower draft losses than multi-pass units. The trend is toward the use of units of great capacity, both in square feet of heating surface and in steam output. A boiler at the East River Station, New York, Fig. 2, contains 60,706 sq. ft. of water heating surface and has produced 1,250,000 lb. of steam per hour. Maximum tube length is 36 ft. Certain new boilers, as Fig. 1, have a small amount of water heating surface, often single-pass, followed by large superheating, steaming economizer and air-heater surfaces.

Unit system plants with one boiler per turbine, each with its essential auxiliaries, as, for example, Gould St. Station, Baltimore, are now in service. A recent study* shows that the availability factor of large output boilers is about 85 per cent while the average availability factor for turbines is about 90 per cent. The availability factor for boilers appears to increase and the cost of maintenance per million pounds of water evaporated to decrease with increased boiler output. High efficiency of large steam generators is maintained over a wide range of load, from 86 to 83.5 per cent over a range from 250 to 550 per cent of rating being attained in the Charles R. Huntley Station in Buffalo.

Steaming economizers are used with high temperature feed water. Air heaters serve with or without economizers to provide air temperatures in the neighborhood of 350 deg. F., for stokers and 400 to 650 deg. F. for pulverized coal.

*From a paper submitted by the American Comittee to the International Electrical Congress, in Paris, June, 1932.

**Professor Mechanical Engineering, Johns Hopkins University, Baltimore.

*Performance of Modern Steam Generating Units, C. F. Hirshfield and G. A. Moran, A.S.M.E. 1931.

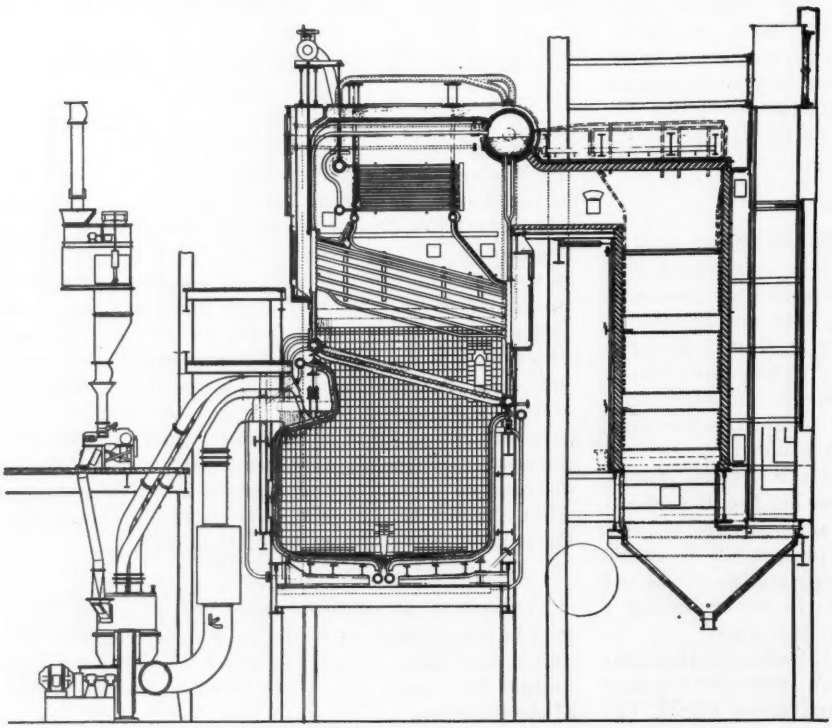


FIG. 1. B. & W. STANDARD BOILER FOR STATE LINE STATION EXTENSION

Installation includes 2 reheat boilers and 3 standard boilers, whose dimensions are:

Surface	Sq. Ft.	
Boiler	8939	
Water wall	3283	
Superheater	8622	
Economizer	31200	
Air heater	80200	
Feedwater	441	deg. F.
Pressure	1300	lb.
Temperature	835	deg. for capacity 500,000 lb. steam per hour.
Furnace Vol.	13,775	cu. ft.
Heat release	42,800	B.t.u. per cu. ft.

High heat absorption rates prevailing in large output boilers and in water walls have developed problems of water circulation and of water levels in drums. These difficulties are being studied for correction in new design. Frequently drums of horizontal water-tube boilers are placed at a high elevation to provide a greater static head on the water in the tubes; some dry steam drums are coming into use on large boilers

units. Heat liberation rates vary from 20,000 to 80,000 B.t.u. per hr. per cu. ft. of furnace volumes with stokers.

Forced draft chain grate stokers are used for free-burning coals, lignites and anthracite, the largest chain grate having 528 sq. ft. of surface, burning 65 lb. coal per sq. ft. per hr. at maximum output and having a furnace heat release of 42,000 B.t.u. per cu. ft. per hr.

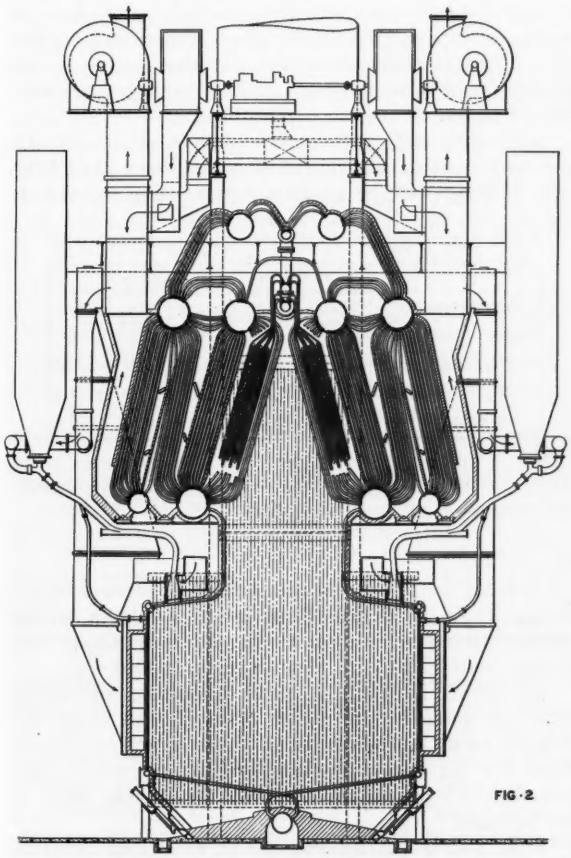


FIG. 2. COMBUSTION ENGINEERING CO. BOILER, EAST RIVER STATION, LARGEST IN WORLD.

Dimensions are as follows:

Surface	Boiler	Water wall	Superheater	Air heater
Sq. Ft.	60,706	7,345	3,900	38,200

Feedwater, 360 deg. F.; pressure, 425 lb.; temperature, 725 deg.; air temperature, 432 deg.; furnace volume, 38,200 cu. ft.; heat release, 25,300 B.t.u. per cu. ft. max.; maximum output, 1,250,000 lb. steam per hour.

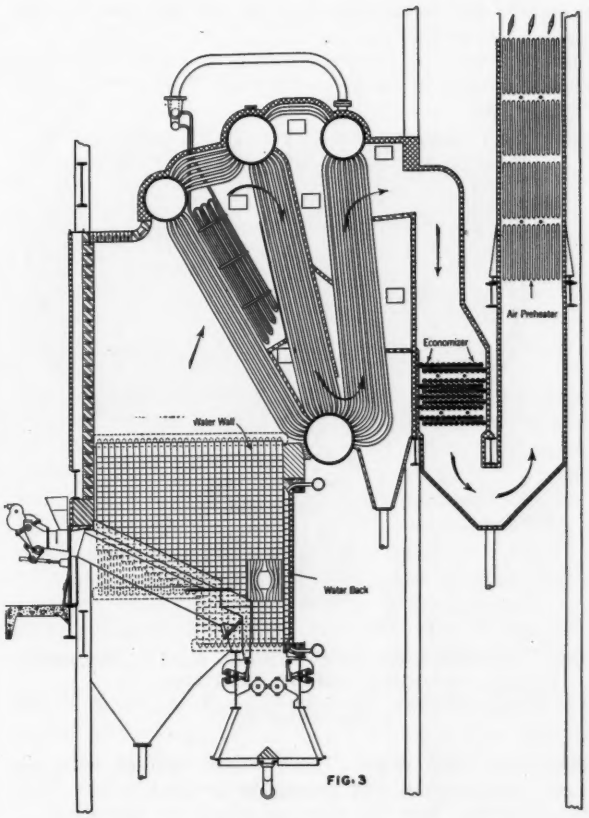


FIG. 3. FOSTER-WHEELER BOILER, MOORE'S PARK STATION

Dimensions as follows:

Surface	Boiler	Water wall	Super-heater	Econo-mizer	Air heater
Sq. Ft.	18,760	846	3900	8400	19,320

Taylor stoker, 440.6 sq. ft. projected area; furnace volume, 10,369 cu. ft.; maximum output, 200,000 lb. per hour.

As quick starting is important, motor-driven centrifugal feed pumps with steam-driven reverse are usual. Motor-driven multiple plunger feed pumps will be installed in a new 1200-lb. plant where their overall efficiency of 77 per cent at full load is sufficient justification for their high cost and great floor space requirements.

Furnace Equipment

Projected area, fuel-burning capacity and efficiency of underfeed stokers have greatly increased. A recent installation will burn 73 lb. per sq. ft. per hr. on 694 sq. ft. at a heat liberation in the furnace of 51,000 B.t.u. per cu. ft. per hr. Width is 26 ft., length 26 ft. 7¾ in.; height from floor to center line of mud drum, 19 ft. 9 in. Zoned air control, improved pusher mechanism, better tuyeres, water-cooled side walls, deeper ash pits and more rugged clinker grinders characterize the newer

For pulverized coal firing, the unit system is gaining in favor, as it provides a cheaper and simpler plant than the central system. Unit mills up to 50 t. per hr. capacity are in operation. Burners of the turbulent mixing type give better combustion and require smaller furnaces than the earlier long flame burners.

Coal is now dried in the pulverizers by preheated air, vent discharges delivering to the furnace, thus eliminating dust nuisance. Many new boilers under which coal with low-fusing ash is burned have furnaces for vertical coal firing and with water-cooled, refractory-lined bottoms on which the ash accumulates as liquid slag and from which it is tapped-off in liquid form as in Fig. 1. A greater proportion of the total ash in the coal is retained in the slag than would be deposited in dry-bottomed furnaces.

Recent practice indicates a heat release in powdered

coal furnaces of 12,000 B.t.u. per cu. ft. per hr. for plain refractory walls, 16,000 for air-cooled walls and 24,000 to 38,000 for water-cooled walls. Average yearly efficiencies of boiler plant of 80 to 88.3 per cent, based upon the higher heating value of the fuel have been obtained.

Limitation of boiler capacity through the deposit of ash as slag on the tubes above stoker and pulverized coal furnaces has been overcome by rearrangement and wide spacing of the first boiler tubes into a "slag-screen." This cools and hardens the ash particles by

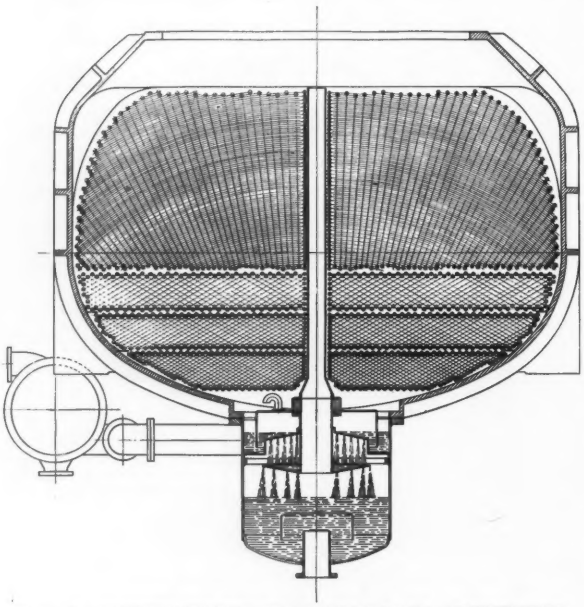


FIG. 4. FOSTER-WHEELER SINGLE-PASS CONDENSER, SOUTH AMBOY STATION
For 29.5 in. vacuum. Tubes 20 ft. by ⅞ in., No. 18 B. w.g. Surface 20,500 sq. ft.

absorbing their radiant heat before contact with the tubes, so that the ash passes on as dust.

Steam Turbines

Sixty-cycle turbines operate at 3600 and 1800 r.p.m. with a few at 1200 r.p.m. For a given casing, the capacity is limited by the allowable length of the last blades and by permissible leaving losses, maximum tip speed of 1200 ft. per sec. having been reached and, in certain cases, leaving losses up to 7 per cent of the adiabatic heat drop. Single cylinder units of 80,000 kw. and tandem units of 160,000 kw. capacity, all at 1800 r.p.m., are in operation. The largest single-cylinder condensing unit at 3600 r.p.m. is rated at 10,000 kw., while tandem condensing units of 15,000 kw. capacity are installed at this speed.

Erosion by moisture in the last rows of blades is due to insufficient superheat for the range of expansion. Much attention is being given to this problem, heavy round-edged blade sections being used in place of the earlier feather-edged blades. Various blade materials such as stainless steel, nitralloy, heavy chrome-plated steels and blades shielded with tungsten, tantalum and stellite are under trial. Schemes for removing moisture from the last stages of steam turbines appear to be effective in some units, but of little benefit in others.

Satisfactory operation of the Detroit Edison Co.'s turbine of 10,000 kw. capacity with initial conditions of 375 lb. and 1000 deg. F. will, in all probability, lead to a substantial increase in initial steam temperatures for new power plants.

Use of a high-pressure oil supply to float the bearings and of motor-driven turning gear has enabled operators to shorten starting time and to eliminate wear of bearings.

Closed bleeder-heaters are generally used but jet heaters are increasing in number, evaporators to furnish distilled make-up water forming part of the bleeder feed-heating system, with deaeration generally effected in one of the bleeder heaters.

Both high and low-pressure turbine glands usually have water seals, which require more power than labyrinth packings but, by absolutely preventing steam leakage, decrease make-up requirements and troublesome roof condensation in cold weather.

TABLE I. N.E.L.A. DATA ON CONDENSERS, 1930

Kw. Rating	Sq.Ft.per Kw.		G.P.M.per Kw.		Aver. Size Kw.
	Single Pass	Multi Pass	Single Pass	Multi Pass	
50,000 and over	0.70	0.95	1.28	1.00	78,000
30,000 to 50,000	1.05	1.00	1.60	1.27	37,500
To 30,000	1.45	1.43	2.18	1.60	15,200

Condensers

Vacuum of 29 in. is specified and secured where cooling water of 55 deg. F. or less is available for the greater portion of the year. In southern plants with 70 deg. water, 28½ in. vacuum must suffice.

As shown in Table I, large quantities of cooling water are pumped per pound of condensed steam due to high water temperatures in summer and to the demand for the lowest absolute exhaust pressure consistent with the prevailing load and the leaving losses of the turbines.

Four trends characterize recent condenser practice: Better distribution of cooling surface has increased its effectiveness and lessened the pressure drop through the tube bank; undercooling of the condensate is prevented by introducing exhaust steam into the hot well; leakage of cooling water into the condensate has been practically eliminated by rolling both ends of the tubes into the tube sheets, which may be floating or fixed; effective sub-cooling of the air pump suction has increased the available vacuum. Figure 4 shows a recent condenser design embodying these improvements.

Where ample supply of cooling water is available at low head, single-pass condensers are favored, two-pass condensers being installed when cooling water is limited or where the lift is high or extremely variable, as on certain rivers and tidal waters. Table I from N.E.L.A. sources gives some figures on American practice with single and two-pass condensers. Tubes are usually ⅞ in. diam. for single-pass and 1 in. diam. for two-pass condensers.

Use of welded plate construction for the condenser shell is increasing, to give less weight and first cost. Steam-jet vacuum pumps are almost universally used. Traveling screens are standard equipment on the intakes of cooling water channels, these intakes being

located as far below the water surface as possible to draw from the cooler water at the lower depths.

Reducing Power Costs

Station performance is determined by the economic influences upon the unit cost of power of the price of fuel, load factor and rate of system growth. Moderate load factors and low fuel costs do not warrant large plant investments to secure high thermal efficiency but, when both fuel costs and load factors are high, thermal efficiency becomes a major factor and plants are designed to secure the best possible performance.

Cost of power consists principally of fixed charges upon the investment in plant and of operating and maintenance expenses. Plant investment can be reduced by larger units. If higher pressures and temperatures are employed, fuel costs can be reduced, while unit combinations of one boiler for one turbine will simplify piping and auxiliary arrangements and, by permitting full automatic operation, will lower operating costs. Many turbines are now purchased with most economical load at 60 per cent of rating, which allows a margin for peak load and emergency demands.

TABLE II. DATA OF MERCURY VAPOR PLANTS

	Hartford	Kearny	Schenectady
Load on mercury turbine, kw.	10,000	20,000	20,000
Speed of mercury turbine, r.p.m.	720	900	900
Total steam from unit - lb. per hr.	129,000	325,000	325,000
Steam pressure, lb. gage	275	365	400
Steam temperature, deg. F.	680	750	760
Mercury vapor pressure at turbine - lb. gage	70.7	125	125
Mercury vapor temperature at turbine - deg. F.	884.5	956	956
Vacuum of mercury condenser, in. abs.	1.5	3.0	3.0
Temp.of mercury vacuum, deg. F.	440	485	485

Attention is being directed to the possibilities of reconditioning and increasing the capacities of old stations, as these can often carry the low-load-factor portion of the demand at least total cost. Frequently this reconditioning provides added system capacity at less cost than can be secured by any other means.

Although the elimination of the power house structure to lower first cost of plant is under consideration and two out-of-door plants are being constructed, one with the boilers unhoused and the other with the turbines outside, the elimination of superstructure may not offer as great an opportunity for cost reduction as simplification of design.

Binary Vapor Plants

Diphenyl oxide is being circulated through economizers in one of the newer stations and serves to preheat air entering the furnace; also it is proposed to use diphenyl oxide in a new station both to superheat the high-pressure steam and to reheat it between cylinders.

Besides the mercury boiler and turbine which have operated successfully in series with a steam turbine at one of the plants of the Hartford Electric Light Co., two mercury plants of 20,000 kw. are under construction. One is at Schenectady, N. Y., to deliver power to the N. Y. Power and Light Co. and to send 325,000 lb. of steam per hr. to the works of the General Electric Co. The other, at Kearny Station of the Public Service Electric and Gas Co. of N. J., will deliver steam to turbines in which 33,000 kw. will be generated, thus making, with the 20,000 kw. from the mercury turbine, a total output of 53,000 kw. for the combined mercury-steam unit. Table II gives details of the three plants. The mercury vapor plant appears to be economically justified for a system where fuel costs are high or where the unit with its accompanying steam turbine can be given a constant heavy loading through the year.

American central stations are still undergoing change and development to increase reliability, simplicity and efficiency. Higher operating pressures and temperatures are now recognized as practical and economically justified, the present effort being for the production of more kilowatt hours for every dollar of total expense.

Detecting a Tenth of a Millionth of a Volt

A VACUUM TUBE a thousand times more sensitive than its predecessors in the measurement of minute voltages was announced by G. F. Metcalf and T. M. Dickinson of the vacuum tube engineering department of the General Electric Co. at a meeting of the American Physical Society at Cambridge, Mass., recently. The new "low noise" vacuum tube, technically designated as the Type PJ-11 Pliotron, differs particularly from the usual tube in the degree of vacuum that has been attained. In the ordinary tube, the gas pressure within the tube is of the order of a millionth of an atmosphere; the new tube has been exhausted to a billionth of atmospheric pressure. The "low noise" tube makes it possible to detect voltages of the order 1/10,000,000 v. It has been possible to do this at radio frequencies for some years but when attempts were made to amplify voltages whose frequencies were less than 1000 cycles per second, it was found that voltages of less than 1/10,000 v. were masked by large random disturbances. These disturbances are made audible by a loudspeaker, as a hissing noise.

Reducing this noise between 100 and 1000-fold, the new tube makes it possible to measure accurately voltages as small as one-millionth of a volt and to detect voltages 10 times smaller, at any frequency from zero (direct current) to a million or more cycles per second.

Laboratory investigations show that random disturbances in the usual tube are caused by any or all of such happenings as insulating material in or near the electron path, irregularity of filament emission, gas, positive ions emitted by the filament and insulating or foreign deposits on grid wires. Having located the causes of the disturbances, the engineers then minimized them.

One of the first applications of the new tube has been in the portable electro-cardiograph produced by the General Electric X-Ray Corp., Chicago.

Contraction of the heart muscles is accompanied or preceded by an electric manifestation. When a muscle contracts, its electric potential or voltage differs from that of a muscle at rest. If two points of the body of the patient are connected through a sensitive measuring device, such as a galvanometer, the instrument indicates an electric tension which varies with the heart beats.

The cardiograph records these voltage variations, of the order of a millivolt, so that an analysis of heart action can be obtained.

POWER PLANT ENGINEERING July 15 1932

Measuring the Temperature Rise of Cooling Water

Details of equipment used at Long Beach Station to give reliable readings within 0.1 deg. F. Thermocouples and multi-point recorders give complete satisfaction if properly installed. Data used for calculating pump capacities and for indicating condenser fouling.

By

D. PARK WOOLLEY

Experimental Engineer
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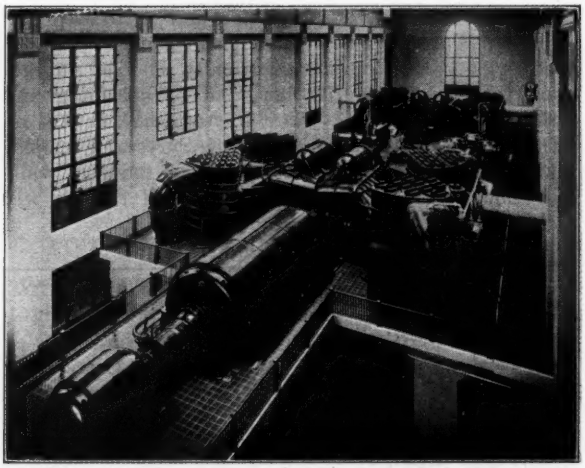
CENTRAL STATION designing and operating engineers are keenly interested in methods and devices which will increase the accuracy of condenser performance data. They know that large savings in operation cost are possible if vacuum and condenser performance can be improved. Only when accurate and consistent data are obtained and compared can the conditions conducive to the best economy be determined. A most important factor in these data is the temperature rise of the cooling water passing through the condenser. Methods used at the Long Beach Steam Station of the Southern California Edison Co., Ltd., accurately to measure this value are discussed. The methods in use at this Station are the result of considerable study and experimental work.

To determine actual daily condenser performance it is essential that the quantity of cooling-water passing through the condenser be known under all operating conditions. This may be determined with a high degree of accuracy by the heat balance method. By this method the rise in temperature of the cooling-water is divided into the quantity of heat given up by the steam in the condenser.

Surface condensers are commonly designed to give a 9 or 10 deg. F. rise in temperature with rated load on the turbine. A 10 deg. F. temperature rise requires that for a determination of the quantity of cooling-water within one per cent accuracy the temperature difference measurements must be accurate to within 0.1 deg. F.

Use of flow meter equipment for measuring the large volume of low-head cooling-water required for condenser operation is seldom desirable. The costliness of accurately designed and installed Venturi tubes makes them prohibitive. Flow-nozzles, or orifices for large pipe lines do not give results within the desired range of accuracy and the loss of pressure head caused by orifice plates has been found to be uneconomical in operation. Growth of algae and shells where ocean water is used soon impairs the accuracy of orifice meters and necessitates frequent cleaning. For these reasons the direct measurement of cooling-water has been abandoned at the Long Beach Steam Station when exact data are desired. Pitot tubes are used to give a rough indication of the flow largely for the purpose of indicating the degree of cleanliness of the condenser.

There are a number of objections to the use of mercury thermometers for obtaining the temperature rise of the condenser cooling-water. The difficulty of properly locating the thermometers to obtain the mean temperature of the water at the condenser inlet and outlet; the errors of observation; the errors inherent in the instrument and the fragility of glass thermometers are among the principal drawbacks to their use.



PLANT NO. 3 OF THE LONG BEACH STEAM STATION OF THE SOUTHERN

Two 100,000 kw. units, known as unit 10 and unit 11, are in this station. Ultimate development contemplates 6 more units of equal or greater capacity. Transformers step up generator voltage of 16,500 v. to the transmission voltage of 220,000 v. Complete automatic control systems enable operation of this plant of 200,000 kw. capacity by 15 men, including watch engineer in charge, on each shift. The capacity of this plant increases the capacity of the Long Beach Steam Station to 415,000 kw. The average economy of Plant No. 3 for the year 1929 was 12,848 B.t.u. per net kw.-hr. Unit 11 (in the foreground) and unit 10 Long Beach Steam Station. Turbines are tandem compound, nameplate rating 94,000 kw. Gross operating rating 100,000 kw. Four vertical, 20,000 sq. ft. single pass condensers serve each turbine

Stratification of Water in Pipes

In order to obtain the mean temperature of water flowing in a large pipe line, several feet in diameter, with glass-mercury thermometers, it is necessary to use a number of thermometers placed at intervals around the pipe. Temperature stratification must be investigated to determine the least number of thermometers necessary for an accurate measurement. The short small bulb of a glass-mercury thermometer precludes the possibility of this type of thermometer extending into the pipe far enough to traverse the cross-section and therefore the temperature indicated is for a very small part of the volume of water flowing in the pipe.

Errors of observation depend upon the eyesight and judgment of the individual reading the thermometers, but in no case can they be considered negligible and therefore must be determined. The accuracy of the readings, will, also, be affected by the rapidity with which the mercury column changes position and in cases where the variation in temperature of the cooling-water

fluctuates rapidly many readings must be made to secure reliable average results. Likewise, the time interval elapsing between reading the many thermometers is another factor in making the glass-mercury thermometer method an unsatisfactory manner of securing the true mean temperature of the cooling-water.

Reliability of a certified glass-mercury thermometer depends entirely upon its method of calibration. This is usually done by checking a few points along the stem, the thermometer being under atmospheric pressure. When the bulb of an ordinary glass-mercury thermometer is introduced into a pipe line and is subjected to ten or more pounds additional pressure at constant temperature, an appreciable increase in its reading will be obtained. The pressure drop through a condenser is usually sufficient to make an error of 0.1 deg. F. Hence, it is necessary to calibrate each thermometer under exactly the same pressure conditions under which it will be used. If the thermometer is placed in a short oil filled well to overcome the influence of pressure and to protect the bulb the chances of an error by conduction make the accuracy of the readings questionable. These objections to the use of glass-mercury thermometers have caused the discontinuance of their use where high accuracy of temperature measurement is desired.

Investigations by the U. S. Bureau of Standards** and others have demonstrated that electrical resistance thermometers are capable of a high degree of accuracy especially where temperature-difference measurements are desired. The small range of the condenser cooling-water temperatures which ordinarily vary between 50 and 90 deg. F. makes it possible to use inexpensive copper wire whose temperature-resistance characteristics in this interval is accurately linear. Resistance thermometer coils can be made of any desired length and their resistance will measure the average temperature of the water passing around them.

Use of Multipoint Indicators

At the Long Beach Steam Station multiple-point electrical temperature recorders were chosen for the purpose of obtaining the temperature-difference between the injection and overflowing cooling-water. The instrument is guaranteed to have an accuracy of 0.1 deg. F. on temperature-difference measurements within the temperature ranges encountered in operation.

Arrangement of the cooling-water piping, condensers, and pumps for the two 100,000-kw. units in Plant No. 3 of the Long Beach Steam Station is shown in Fig. 1. Steam from each of the turbines exhausts into four vertical condensers. The condensers are single pass with 20,000 sq. ft. of surface each. Two condensers stand to the north and two to the south of each low-pressure turbine. The condensers are numbered from the turbine throttle, N-1, N-2, S-1 and S-2 on each unit. There are four temperature recorders for the two units and each instrument records the temperatures for two condensers.

Temperature recorders use a 10 in. wide roll-chart with a temperature scale reading from 50 to 110 deg. F. and a temperature-difference scale reading from 0 to 15 deg. F. The smallest division on the chart is 0.4 deg. F. for temperature and 0.1 deg. F. for temperature-difference measurements. Small divisions on the chart are equally spaced and are approximately 1/16 in. wide. The printed record can be estimated to about one-quarter of one small division, giving reading of 0.1 deg. F. for recorded temperature and 1/40 deg. F. for recorded temperature-difference. Temperature or temperature-difference readings are, however, not considered this accurate. A sample record obtained is shown in Fig. 3.

Figure 2 shows the application of the Callendar or loop-system of compensation for the effects of the resistances of the thermometer leads in temperature-difference measurements. It will be noted that there are four

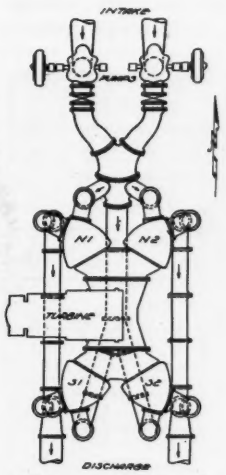


FIG. 1. PLAN OF CONDENSERS WITH COOLING WATER PIPING OF UNIT NO. 10

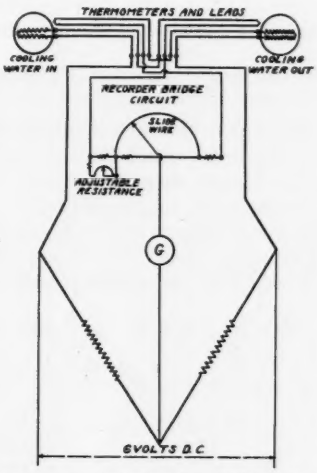


FIG. 2. WIRING DIAGRAM SHOWING LOOPED-END SYSTEM OF COMPENSATING FOR THE RESISTANCE OF THE THERMOMETER LEADS IN TEMPERATURE - DIFFERENCE MEASUREMENTS

lead wires to both the injection and outlet water thermometers in the measuring circuit.

In the case of each thermometer the two lead wires joined to the ends of the thermometer coil are connected in one arm of the bridge, and the other two lead wires which are dummy leads formed of a single loop running through the same conduit and extending to the top of the thermometer coil are connected in the opposing arm of the bridge. The two pair of lead wires are alike so that variations in temperature, in any part of the conduit, affect each equally.

Lead wires from the recorders which are mounted on the condenser gage board to the thermometers located in the water pipe lines are from 50 to 150 ft. in length, depending on which point is taken, but all of the lead wires to any one point are of the same length. Number 16 B. & S. gage solid copper wire is used.

An adjustable resistance is placed in the measuring circuit which makes it possible to compensate for any small inequality in resistance between the two arms of the bridge. This is very helpful because it is practically impossible to make the lead wires in either arm exactly equal in resistance.

All of the thermometers are wound with copper wire and have approximately 10 ohms resistance at 77 deg. F.

** Scientific Paper (Bulletins) of the U. S. Bureau of Standards; No. 68, Calorimetric Resistance Thermometers and the Transition Temperature of Sodium Sulphate, by H. C. Dickinson and E. F. Mueller; No. 147, The Temperature Coefficient of Resistance of Copper, by J. H. Dellinger; No. 200, New Calorimetric Resistance Thermometers, by H. C. Dickinson and E. F. Mueller; No. 241, A Wheatstone Bridge for Resistance Thermometry, by C. W. Waidner, H. C. Dickinson, E. F. Mueller, and D. R. Harper, 3d.

The length of the distributed coils of the temperature-difference thermometers is equal to the diameter of the pipes in which they are placed. The coils are wound on ⅛-in. cambric insulated rods and covered with a single layer of varnished silk to protect them from grounding on the wells. The wells are made of 1 in. O.D. stainless steel and in the vertical pipe lines are supported at both ends.

Principal desirable features of installation described, lie in the use of looped leads to compensate for temperature variations along either pair of thermometer lead wires and an accurate balance of the bridge circuit external to the recorder. Also, in place of the regular 125-v. d.c. control current through resistors as first designed, a 6-v. storage battery and 2 ampere trickle charger are now used on the recorders. This has been found to give much better service than the higher voltage current, which was troublesome due to frequent ground-

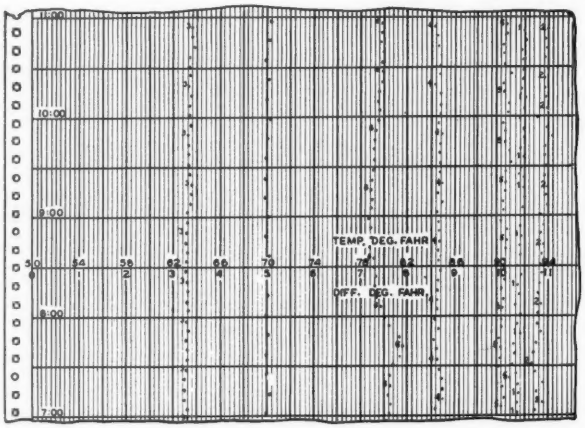


FIG. 3. PORTION OF CONDENSER TEMPERATURE RECORDER CHART. POINT 1, TEMPERATURE OF EXHAUST STEAM. POINT 2, TEMPERATURE OF THE CONDENSATE IN THE HOTWELL. POINT 3, TEMPERATURE OF THE INJECTION WATER. POINT 4, TEMPERATURE-RISE COOLING-WATER CONDENSER N-1. POINT 5, TEMPERATURE-RISE COOLING-WATER CONDENSER N-2. POINT 6, TEMPERATURE OF AIR LEAVING NORTH INTERCOOLERS. POINTS 1, 2, 3, AND 6 REFER TO THE 50 TO 110 DEG. F. SCALE. POINTS 4 AND 5 REFER TO THE 0 TO 15 DEG. F. SCALE. CHECK-POINT SHOULD FALL ON THE 70 DEG. AND 5 DEG. LINE

ing. A 0.5 ampere fuse has been inserted in the battery circuit to protect the coils from too high a current and consequent overheating in the event that part of the circuit is shorted out.

To determine the reproducibility of results by the recorder a check point is provided on the selector switch which cuts out external circuits and allows the bridge slide wire to be balanced against a standard resistance contained in the recorder. Operation records over a long period of time have proven that the recorder, when properly adjusted and with the electrical contacts free from dirt, has a variation in the check point of less than 1/20 deg. F. To maintain this precision it has been found necesary to clean the contacts with benzol about once a week. A variable check point record usually indicates that the moving contacts need to be cleaned.

Finding the Zero Point

Previously the practice was to set the recorders for zero balance with the turbine down and the cooling-water pumps running. This assumed that both the inlet and outlet thermometers were at the same temperature and that the recorder would give the correct temperature-difference when the turbine was operating. This method did not allow sufficient freedom in checking the recorders, and therefore two sensitive 100-ohm nickel wire thermometers were made to fit in extra thermometer wells in the water pipe lines. The recorders are now set under regular operating conditions by using these 100-ohm thermometers placed in the extra wells in the inlet and outlet water pipe lines and connected to a portable semi-precision thermometer bridge and a galvanometer for detecting a condition of electrical balance in the bridge.

It was necessary to determine the resistance increase of these 100-ohm nickel thermometers per deg. F. as well as the difference in resistance between them at the same temperature. They were very accurately calibrated in an adiabatic calorimeter apparatus against two precision calorimeter thermometers which had been certified by the U. S. Bureau of Standards.

The field set-up for checking the recorders consists of the two 100-ohm thermometers placed in the extra thermometer wells, one in the inlet line and the other in the outlet line. These are connected to the portable thermometer bridge by means of the looped lead system of compensating for the temperature effects of the lead wires. The turbine is operated on blocked load and the difference in resistance between the outlet and inlet 100-ohm thermometers is measured every time the recorder is ready to print. The resistance measurements are converted to degree F. by reference to calibration curves. The recorded readings are made to agree by properly adjusting the compensating dials provided for this purpose in the bridge circuit.

Check Readings

This method is occasionally checked by running the circulating pumps with the turbine shut down under which conditions there should be a negligible temperature-difference between the inlet and outlet thermometers, in other words, the recorder should balance on zero. The two methods have been found to agree well within 0.1 deg. F.

Exact measurement of the rise in temperature of the cooling-water may be used for cooling-water pump capacity tests. These readings also serve as an indication of condenser fouling. Likewise, where there is more than one condenser serving the same unit, as is the case in Plant No. 3 of the Long Beach Steam Station, the relative fouling of the condensers is evident. In the case of the installation referred to, the temperature rise of the cooling-water is allowed to increase 1 deg. before it is considered that the expense of cleaning is justified.

Figure 3 shows a portion of temperature recorder chart for the two north condensers N-1 and N-2 serving Unit 11. This portion of the chart was made on the morning of November 12th. This record is of particular interest because it shows the difference in results produced by a clean and a dirty condenser. During the night N-2 condenser (point 5 on the chart) was cleaned with rubber plugs. Because of the better heat transfer the temperature of the cooling-water passing through N-2 condenser is raised 1.4 deg. F. higher than the temperature of the cooling-water passing through N-1 condenser (point 4) which has not been cleaned. When

all four condensers are clean the temperature rise is about the same in each condenser and is in the neighborhood of 9 deg. F. at maximum load.

Instruments in use at Long Beach record the temperature of the injection water, the temperature of the exhaust steam, the temperature of the condensate in the hotwell and the temperature of the air leaving the intercoolers. All these data, together with the temperature rise of the cooling-water make a permanent record of the condenser operation which is a guide to both better operation and better maintenance.

Operating conditions at the Long Beach Steam Station are favorable for experimental investigation of the nature described. A large portion of the year Plant No. 3 is operated at practically constant load. Even during the period it is used for regulating the system load the machines can be operated for an hour or more on blocked load. This kind of operation has resulted in a close adjustment of the automatic steam pressure control which usually maintains the steam at the turbine throttle within a range of 3 lb. above or below the desired pressure.

Block load conditions are maintained by means of a special blocking device attached to the governor arm. This device is adjustable to any desired load and restrains the governor arm from greater opening of the steam inlet valve. The blocking device is suspended from the governor arm by a pinched ball joint on which the tension is adjusted to pull apart on a half cycle drop in turbine speed. This feature releases the governor to enable the unit to take all the load it can in the event of low system frequency.

Experimental work which furnished the material for this article was carried out by the Efficiency Division of the Steam Generation Department of the company under the direction of L. J. Kraps, efficiency engineer.

Diesel Power for Station KSTP—

STATION KSTP, National Battery Broadcasting Co., located 12 min. south of St. Paul, Minn., is stated to be the first large radio station in the United States using Diesel power for the operation of its equipment. The postal station is called Radio Center and the radio station is sometimes referred to by that name. Until a year ago, KSTP was a 5000-w. broadcasting station, operating on a frequency of 1460 kilocycles. Recently the company obtained a permit from the Federal Radio Commission to increase the radiation to 10,000 w. with the possibility of increase, at a later date, to 18,000. w.

One of the most important items in any broadcasting system is a reliable, continuous electrical service. Inasmuch as this station operates on an average of 19 hr. per day, economy is also an important consideration. For these reasons, during the construction of its plant, careful investigations were made as to the desirability of purchasing power from a large central station or of generating power by means of a Diesel engine. It was estimated that the average load would be 85 kw. for 19 hr. per day. Current required was 3-phase, 60-cycle, 480 v. and the total kilowatt-hours required over a period of one year would be 589,475.

On this basis, the purchased power cost would be $8678 per yr., or an average of 1.47c per kw-hr. It was estimated that a Diesel generating unit would show low operating costs and a cost per kilowatt-hour lower than for purchased power.

A 210-hp. Fairbanks-Morse 3-cylinder, 14 by 17-in. Diesel engine operating at 300 r.p.m., direct connected to a 167-kv-a., 133-kw., 3-phase, 60-cycle, 480-v. engine type alternator was installed, with the necessary exciter, switchboard, cooling tower, air starting equipment and other such apparatus. This unit was of sufficient size to allow for an ultimate radiating capacity of 18,000 w., at which time it is estimated that the load will be approximately 110 to 120 kw.

Precautions Needed in Using Diesel at Radio Station

Certain difficulties must be considered in the installation of a Diesel generating unit in radio station.

1. The foundation must be thoroughly insulated to prevent any possible vibration from being transmitted to the transmitter room, as the tubes in the transmitter are very sensitive. The foundations at KSTP are insulated from the ground with 12 in. of fine sand.

2. Because of the intense electromagnetic field at such a location, the entire unit as well as the alternator and all auxiliary equipment must be heavily grounded.

3. The exhaust stack should not extend above the roof of the building and, in addition, excellent silencing must be provided so that exhaust noise will create no objectionable air vibration. This is readily accomplished at KSTP by a concrete exhaust silencing pit and a Fairbanks-Morse silencer.

4. Voltage regulation must be controlled within close limits so as not to affect either the life of the radio tubes or the broadcasting itself. This was accomplished through installation of a Tirrill voltage regulator.

5. The frequency must be controlled within ½ of 1 per cent. This was also readily accomplished at KSTP. Incidentally, the U. S. Government has a radio testing station at Grand Island, Nebr., which checks the wave lengths and reception from radio stations throughout the United States, also operated by Fairbanks-Morse Diesels.

The power plant at Radio Center is a complete installation in itself. A water softener is used to treat the water used up by evaporation. A cooling tower, constructed over a concrete basin, has eight spray nozzles and receives its water at approximately 8 to 10 lb. pressure. A bypass arrangement is made around the tower so that during the winter months the water can be bypassed directly back to the basin without using the nozzles. A centrifugal pump driven by a 3-hp. electric motor pumps water from the cooling tower basin, through the engine, back through the spray nozzles and into the basin again. This pump unit is wired so that when the Diesel generating unit is started up in the morning, it obtains its energy from the alternator fields at 440 v. and gets up to speed practically as soon as does the generating unit.

No operator is required for the operation of the Diesel generating unit. The radio operator makes a tour of inspection once every two or three hours to check the fuel and lubricating oil supply. An automatic water thermostat is so arranged that, if the temperature of the water exceeds 150 deg. F., an alarm sounds in the radio station proper and steps may be taken to correct the condition. All electrical instruments are located in the main radio station so that the voltage and current being generated may be noted at any time.

POWER PLANT ENGINEERING July 15 1932

High Pressure Boiler Availability at Lakeside

FOUR 1390 LB. BOILERS SHOW 92 PER CENT AVAILABILITY FOR THE YEAR 1931 AND A TOTAL LABOR AND MAINTENANCE COST OF $16,189.93 FOR 24,752 BOILER HOURS OF OPERATION. THIS IS EQUAL TO ABOUT $0.65 PER HOUR OF OPERATION. BY G. G. POST, VICE PRESIDENT IN CHARGE OF POWER, THE MILWAUKEE ELECTRIC RAILWAY & LIGHT CO.

AVAILABILITY of high pressure boilers can by proper design and operation be brought up to that of low or medium pressure units. This has been well demonstrated by several years' records of the 1390 lb. units at Lakeside[1]. During 1931 the average availability of the four high pressure boilers was 92 per cent as shown by Table I.

Boiler No. 17, the first high pressure unit installed in 1926 had the poorest record with an availability of 82.3 per cent. This cannot, however, be considered as typical performance because the unit was out of service during the latter part of the year to permit the original square section radiant superheater elements to be replaced with tubular elements[2]. At the same time a considerable amount of work was done replacing boiler tubes which were causing trouble due to deposits dating back to the early development period in 1926.

Operation of this boiler during the past year is not representative of what may be expected later. Exclusion of this unit increases the availability of the three remaining units to 95.2 per cent and decreases the times out for repairs to 12, an average of one outage in four months for each boiler.

This record was made in the face of extremely variable load conditions with two and sometimes three of the four units out of service each night. Sometimes one or two units were used for a few hours only to carry Saturday or Sunday evening peaks.

The remarkable flexibility of this type of reheat boiler is shown not only by the above availability figures but by the maintenance cost as shown by Table II. Excluding No. 17 because of the design change previously mentioned, the total labor and material maintenance cost of the three remaining boilers was but $3,420.29 for the entire year. These three boilers operated 71.8 per cent of the time or about 18,850 boiler hours, bringing the cost per boiler hour down to about $0.181. Even with the unusual expense of some $12,000 for replacement of the old type elements on No. 17, the total cost was but $16,189.93 for 24,752 boiler hours or about $0.65 per hour.

Data on the high pressure section of the station since the first installation in 1926 are shown by Table III. The first boiler's availability was low (65 per cent) for the first 14 mo. because of scale and corrosion troubles. Reheater tube replacements limited its availability to approximately 86 per cent until the new elements were installed last fall.

[1]See Power Plant Engineering Aug. 15, 1931, p. 830, for a record of the development of Lakeside since 1920.
[2]See Radiant Superheater Developments by M. K. Drewry, Power Plant Engineering, p. 128, Feb. 1, 1932.

TABLE I. AVAILABILITY OF THE FOUR BOILERS FOR 1931

Boiler No.	17	18	19	20	Average All Boilers
Number of times out for repairs	6	5	4	3	
% of time in operation	86.9	68.1	73.2	74.3	70.6
% of time idle but ready for service	15.4	24.8	21.8	23.5	21.4
% of time out for repairs	17.7	7.1	5.0	2.2	8.0
% total availability	82.3	92.9	95.0	97.8	92.0

TABLE II. COST OF MAINTENANCE ON THE FOUR BOILERS

Cost of Maintenance Labor (Incl. Shop Labor)					
Boiler No.	17	18	19	20	All Boilers
Boiler and Screen Tubes	$4215.70	0	$22.50	0	$ 4238.20
Superheater and Reheater	1417.31	$152.56	32.69	$69.16	1681.72
Furnace	1314.21	6.24	727.39	9.78	2057.62
Other miscellaneous equipment on boiler	1054.01	245.59	679.44	123.94	2102.98
Total -	$8001.23	$414.39	$1462.02	$202.88	$10080.52

Cost of Maintenance Material					
Boiler No.	17	18	19	20	All Boilers
Boiler and Screen Tubes	$2544.52	$ 20.56	$ 1.50	$ 12.96	$ 2579.54
Superheater and Reheater	1533.92	17.08	4.44	4.24	1559.68
Furnace	309.68	82.12	479.65	3.04	874.49
Other miscellaneous equipment on boiler	380.29	265.82	368.01	81.58	1095.70
Total -	$4768.41	$385.58	$ 853.60	$101.82	$ 6109.41

Labor and Material					
Boiler No.	17	18	19	20	All Boilers
Total -	$12769.64	$799.97	$2315.62	$304.70	$16189.93

TABLE III. SINCE 1926 THE AVAILABILITY HAS INCREASED FROM 66 TO 92 PER CENT

Year	1926	1927	1928	1929			1930					1931				
Boiler No.	17	17	17	17	19	Both	17	18	19	20	All	17	18	19	20	All
Hours operated	1037	5467	6945	7450	1528	8978	6750	1838	7419	195	16204	5861	5969	6412	6510	24752
Elapsed hours	1608	8760	8784	8760	1848	10608	8760	2769	8760	217	20506	8760	8760	8760	8760	35040
Per cent use factor	65.4	62.4	79.1	85.0	82.7	84.6	77.1	66.4	84.7	90.0	79.0	66.9	68.1	73.2	75.0	70.6
Per cent availability	66.0	63.8	84.3	89.1	85.8	88.5	86.6	91.7	89.6	90.0	88.6	82.3	92.9	95.0	97.8	92.0

Boiler Cleaning For Economy

By REGINALD TRAUTSCHOLD*

Whether Steams Costs 25 Cents or 50 Cents for 1000 lb. May Depend on Boiler Cleanliness. Often Investment in an Effective Cleaner Yields Big Returns on the Investment.

RESUMPTION of profitable business calls for drastic economies in power plant operation as well as in factory and mill. Every department of a business will have to cut its costs, in efforts to balance the budget. Since power costs are looked upon by some managers as especially burdensome, the power plant, in particular, will be called upon to effect savings. Reduce the power cost burden and production expenses can be lowered is the attitude commonly assumed.

Unit Treatment Essential

As the power plant is not an entity in itself but consists of more or less independent units, the desired economy in power plant operation is to be realized only by studying the operation of the several units separately, then fitting each into the power plant assemblage so that under the existing conditions it may do its full share of the work effectively and function harmoniously with the other units.

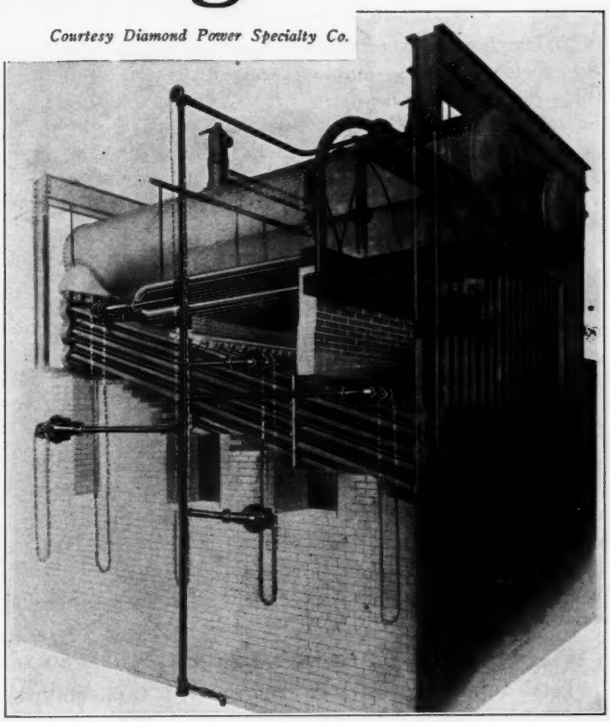
Final Cost Is What Counts

No universal formula or hard and fast rule can be given for modernizing a power plant. Local conditions and requirements vary too widely. But the universal measure of attainment is the cost at which results are secured. Nothing else really counts.

One plant may generate steam at a cost of 50 cents per 1,000 lb. while for another the cost may be only half as great, even though the price and quality of fuel may be almost identical at the two plants. With equipment of the two plants modern and efficient, yet some process in the cycle of steam generation may fail to click in one of the plants, possibly in the one that is actually better equipped; some essential process out of step, may result in one plant being penalized by a cost burden twice that carried by the other plant. Difference in basic power cost may not be great but inefficiencies in power utilization and incidental power wastes

*Consulting Engineer

Courtesy Diamond Power Specialty Co.



Modern 5-element blower installation

pyramid so that the power dollar in the two plants is expended for widely differing final results.

Comparison of Detail Costs Most Logical

That rational correction of any situation can be most readily effected when detailed cost items are segregated goes without saying but rarely are statistics pertaining to individual power plant equipment units recorded. Even if they are, their value is lessened by lack of dependable standards for comparison. As conditions in no two plants are identical in all respects, comparative standards are liable to be disregarded or discredited. This is a mistake for, while conditions and requirements in power plants as a whole may differ widely, variation is far less when individual units and processes are considered. Comparisons of itemized expense and attainment furnish information of value and may indicate ways of effecting desirable savings in essential processes.

Whatever the process, or operation, results secured in one plant are of interest to every other plant in which a similar operation is conducted. The plant that can show best results is helped by the ranking it earns, while in the plant where operation is less economical, the equipment and methods needing attention are singled out. If this is done, surprising control over and betterment in power costs will result.

In analyses of power plant equipment units, it is well to make sure that the best possible results are being secured with the existing equipment and an excellent

starting point is to check-up on the cleanliness of the boiler. Dirty boilers are charged with being responsible for about 25 per cent of the existing waste in power plant operation. In many individual plants, the waste from this cause is even much greater.

Mechanical Soot Blowers

Today few plants that are operated economically and efficiently fail to employ mechanical soot blowers. Yet soot blowers have been greatly improved during the past decade and much information has been acquired concerning their proper use, hence here is an excellent opportunity to study the importance of modern equipment and set up suitable cleaning methods and schedules.

Naturally, the central station field affords an exceptional source of information concerning the economic value of modern soot blowers, for the product of the public service plants is power and the economical generation of power is, consequently, of first consideration. Virtually all central stations employ mechanical systems of soot blowing and almost any one can provide pertinent statistics. In the case of the Lynn Gas & Electric Co., Lynn, Mass., for instance, a battery of eleven boilers aggregating some 4580 hp. in rated capacity furnishes some interesting figures. All boilers are equipped with modern mechanical soot blowing systems, the largest unit, an 880-hp. boiler, having ten blower elements; half a dozen 350-hp. steam generators and four 440-hp. boilers have five-element blowers.

Central Station Economies

Total annual cost of soot removal with this equipment—including all carrying charges, depreciation, maintenance, steam and labor costs—is somewhat less than $4200, about 93 cents per horsepower rating per year. Approximate cost of the hand-lance method of soot removal for the eleven boilers, based upon the existing steam and labor rates, would be close to $5500 a year or $1.31 per horsepower rating. Not only is this substantial saving of approximately 22 per cent realized but the gain from reduction of flue gas heat losses accounts for a further fuel saving of 1100 t. of coal a year, valued at more than $6000.

At the Decatur Station of the Illinois Power & Light Corp., which supplies steam heat for commercial buildings and residences, boilers equipped with mechanical soot blowers are used for their greater ease and economy over hand-lance methods. Blowers are operated once each 8-hr. shift, the total time for a thorough cleaning of a single boiler averaging about 4 min. The work is done, incidentally, without interfering with other boiler room duties. On a battery of four boilers, the total annual cleaning costs, taking into account every expense and charge, favor the mechanical system of soot blowing by nearly $3000. Besides, improvement in boiler efficiency is effected by a reduction in draft losses and the elimination of the heat losses incurred when opening the cleaning doors for hand-lancing.

Industrial Plants Make Substantial Savings

When the Youngstown Sheet & Tube Co. made a careful study of the problem of soot removal some years ago, exhaustive tests were conducted on two identical 1500-hp., stoker-fired boilers to determine the relative costs of mechanical and hand-lance soot removal methods. Every possible care was exercised to have operating conditions similar and the findings comparable. Every expense item was accounted for, fixed charges, maintenance and upkeep as well as all operating expenses for labor, steam and supplies. Some of the savings effected by the mechanical soot blowers were:

Direct saving in annual cleaning expenses amounted to over $475 per boiler per year, a reduction of approximately 21.5 per cent with a saving in fuel, due to a reduction of about 45 deg. in the temperature of the flue gases, of close to $2000 per boiler. Incidentally, the total investment for mechanical soot blower equipment installed was a matter of some $4700 per boiler.

In advanced high-pressure steam plant operation, the installation at the Waldorf Paper Products Corp., St. Paul, Minn., is noteworthy. Here, two modern 1200-hp. boilers are operated, generating steam at a working pressure of 650 lb. with 250 deg. of superheat. Each of these boilers is equipped with twenty soot-blower elements of the swinging arm variety, ten installed on each side, while the air preheaters serving these steam generators are provided with six soot-blower elements in staggered arrangement.

Blowers are operated at intervals of 12 hr. and clean the soot from the heating surfaces so effectively that exceptionally high overall boiler efficiencies are maintained continuously and without appreciable variation in rates of fuel consumption. In fact, one of these well cleaned boilers, after continuous operation day and night for a period of three months, functioned at an unimpaired efficiency of 87 to 88 per cent, giving conclusive evidence, not only that the boiler and air preheater were kept clean by the soot-blower system, but that boiler cleanliness is important.

Power Cost Reduction Index

Results such as these may be said to represent goals in the progress to power cost reduction. They provide comparative standards that can be studied to advantage by all steam power plants. Compared to antiquated methods of boiler cleaning, they point to a simple way of effecting important reduction in power costs.

For plants equipped with soot-blower systems, these results provide check measures that are helpful in showing whether their present boiler cleaning costs are justified or whether further modernizing of boiler cleaning methods, schedules or equipment should be undertaken. Today a satisfactory mechanical soot blower system, compared with hand-lance methods, should save at least 1 t. of coal out of 9, eliminate the need for additional labor for routine boiler cleaning and save substantial amounts in refractory and boiler tube upkeep expense.

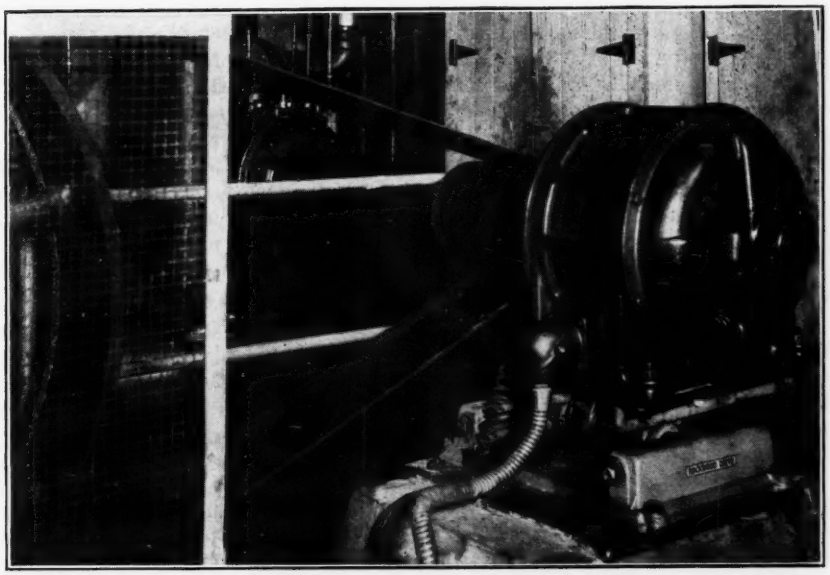
Careful, periodic, check-up on boiler cleaning costs will well repay any power plant but even more important is an accurate determination of the effectiveness of the cleaning. If boiler efficiencies show a tendency to fall off or to fluctuate noticeably between boiler cleanings, an excellent first step is a detailed investigation of existing methods of boiler cleaning, schedules and equipment.

Radical alterations in power plant operating equipment, may well await the attainment of the best results obtainable with existing facilities. Doubtless reconditioning will be necessary at other points but few if any changes will show greater return on the investment entailed than proper provision for keeping boilers clean.

Power Utilization

Belted Motor Drives

By Robert W. Drake



As Used in the Electrical or Millwrighting Department and for Men Operating Small Plants

ORDINARILY a motor belt drive, intelligently planned, gives long and satisfactory service, with no attention except to keep the leather from drying out and one or two belt shortenings when the belt is new.

When conditions change, such as increase of load, speed or output of the driven machine, you must make changes in the belt drive to meet the new conditions.

Possibly a too small pulley drives a large one, on short centers with a violently fluctuating load exhibiting extreme peaks; possibly a motor is operating with pulley considerably smaller than the minimum diameter specified by the manufacturer of the motor, hence develops bearing trouble; belt speed may have to be increased; the motor may run too hot; belt life may seem too short; the belt drive must be changed to adapt it for these conditions as they arise.

The Belt for the Drive

A belt which will carry 10 hp. may not be suited for a 10 hp. motor. Fully one-half of the belted motor applications in industry require a heavier belt for starting than for satisfactory running. Practically all three-phase, a.c. motors which start on the line and many d.c. motors, develop from one-third to one-half more belt pull at starting than when operating at full rated load. Wound-rotor motors sometimes and high-slip, line-start motors (high resistance rotor motors) always, develop *twice* normal full load belt pull at starting

When a.c. line-start motors reach about three-quarters full speed, or when compensator-start motors are thrown over onto the line before they rise much above three-quarters full speed, the belt pull rises to double full load for a time,—a short time with an easy starting load which comes up to speed quickly, a longer time for a slow starting load.

Belt pull during starting is determined by the motor without reference to the requirements of the load. Any torque available, in excess of that necessary to overcome starting resistance is used in hustling the load up to speed more quickly. A belt which will carry an excessive pull momentarily on an easy starting load, will frequently come off, if the same pull persists for several seconds on a load which takes longer to start.

We may overload a belt while starting a load, for we can then tolerate considerable slip. But, after it is up to speed, what is the maximum belt pull likely to be? This is a hard question to answer, as it depends upon the type of driven load. We can, however, set an outside limit.

For loads having high momentary power peaks, such as a drill press when the drill breaks through or on a small group of say three machines, which may occasionally work into step,—on such loads, when confronted with momentary demand for maximum power, most motors will deliver *double* normal full load belt pull. Some high-speed motors and high-slip motors will deliver 2½ times full load pull.

To Increase Drive Power

If the capacity of a drive, planned with motor manufacturer's standard pulleys must be increased because of extreme load peaks or for any other reason, what can we do? A number of expedients will help in such cases:

1. Putting on paper pulleys, if old ones are of wood or metal. 2. Securing higher belt speed by means of

larger diameter pulleys. 3. Using a pivoted motor base. 4. Using gravity idler drives. 5. Putting on a wider belt, if the bearings will stand the extra belt pull with a wider belt to carry additional load.

Occasionally, when conditions are particularly unfavorable, two or three of these expedients must be employed in order to get a satisfactory drive. Two or three are all that are possible in any one case.

Paper Pulleys

Where the smaller pulley of the drive is not paper, an increase of 25 per cent in drive capacity may be obtained by installing a paper pulley. Since all motor manufacturers furnish paper pulleys, they are generally used on the motor but we sometimes lose sight of the fact that in speed-up drives the driven pulley is the smaller and should also be paper. Even on drives where the driven pulley is the larger, a worth-while improvement in capacity and a decrease in slip may be obtained by

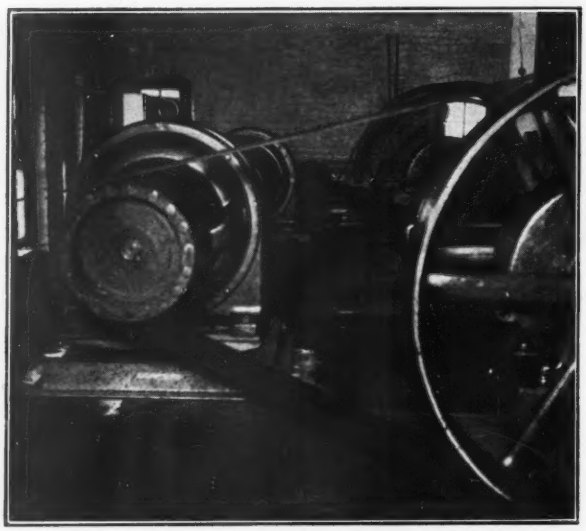


FIG. 2. PIVOTED MOTOR BASE AND GRAVITY IDLER DRIVES

substituting a split paper driven pulley, where the driven pulley is not more than three times as large as the driver.

Higher Belt Speed

The faster a belt is run, up to 5000 to 6000 ft. per min., the more horsepower it will carry but above 4500 ft. per min. the gain in horsepower is rather small.

Except for medium and large 1750-r.p.m. motors and large 1140-r.p.m. motors, manufacturers' standard pulleys give belt speeds decidedly below 4500 ft. per min., hence, in many cases it is possible to increase the horsepower capacity of an existing drive materially by increasing the belt speed without exceeding 4500 ft. per min. The cost of two pulleys and a slight increase in belt length is moderate. Substantial increases in drive capacity are thus easily obtained with no increase in belt width, belt tension, or motor-bearing loads.

On smaller sizes of motors, you can increase the belt speed more than is ever required; on medium sizes, operating at less than 1800 r.p.m., the belt speed can be increased enough for ordinary trouble jobs.

Where the drives carries the load satisfactorily but the motor bearings heat dangerously, by substantially increasing the belt speed, a narrower belt may be used, or the old belt run slack and the bearings greatly relieved.

Wherever the motor pulleys in service are smaller than the sizes tabulated herewith, higher belt speed should be considered first of all when relief is desired for an overloaded drive. Motor speeds and pulley diameters given correspond to 4500 ft. per min. belt speed:

Motor Speed, r.p.m.	1750	1140	850	690	570
Motor Pulley Diam. in.	9.75	15	20	25	30

In some cases, for instance on a large 1800-r.p.m. motor where the belt runs at 4500 ft. per min. or more already, you cannot increase the belt speed. It may be impossible to increase the large pulley size because of interference with ceiling, floor or the frame of the driven machine.

Wider Belts

"Let's put on a wider belt." This is ordinarily the solution which comes to mind when a belt drive operated at reasonable tension will not start the load or fails to carry the extreme load fluctuations.

With motor belts this ordinarily is not the best solution for the problem.

Many plants try to keep all motors of a given horsepower capacity to one speed, so as to simplify the stocking of spare motors for use in case of motor breakdown. In fitting the shop standard-speed of motor to individually-driven machines, cases arise where a wider belt than standard must be used. Perhaps the diameter of the driven pulley is fixed, as for a compressor or a punch press flywheel, in which case the motor pulley must be somewhat smaller than the standard for that motor. Here more belt is needed because of lower belt speed. If you can use a motor pulley that is no smaller than the motor manufacturers' standard diameter, by means of any reasonable expedient, it is the thing to do.

Most troubles from motor drives result from using motor pulleys smaller than the standard. With a smaller pulley, belt life is shortened. By using special, extra-flexible belting you can avoid this, at least in part, if the pulley is not too small. If the pulley diameter is to be decreased, the belt must be wider and in about the same proportion. As this is ordinarily expressed, the product of pulley diameter and face width should be kept the same as for the standard motor pulley. If this cannot be done, then a pivoted motor base or gravity idler is generally advisable.

With a wider belt, the load on the motor bearing will be greater than normal, bearing life shorter and bearing operating temperature higher than normal.

Ordinarily, some allowance is made in the design of motor bearings for over-tightening of belts. All motor manufacturers will furnish data showing the widest belt and the corresponding smallest pulley which any given frame, operated at any given speed, will stand without dangerously overloading bearings. It is worth while for the plant engineer to provide himself with these data covering all lines of motors which he is using. In the absence of such data for a particular motor, a few general suggestions may be helpful.

With the exception of motors built more than 20 or 25 yr. ago and of motors built by two manufacturers whose product was always characterized by particularly rugged bearings, few 1750-r.p.m. sleeve-bearing motors

above 25 hp. will stand any increase in belt width at all. This is likewise true of 1140-r.p.m. motors of 50 hp. and above. Almost all 20 and 25-hp., 1750-r.p.m. motors; 30, 35, and 40-hp., 1140-r.p.m. motors; and 40 to 100-hp., 850-r.p.m. motors will stand at least 20 per cent increase in belt width, some 30 per cent or more. Smaller motors, say up to 10 hp. will generally stand belts 30 per cent wider than standard; many will stand 40, some 50 per cent, the latter particularly in sizes 5 hp. and below.

As to exceptions in the case of sleeve bearing motors, if the bearings with tight standard belts run very hot, wider belts are not to be thought of; if hot, only 10 per cent wider, or 20 per cent, if a pivoted motor base or gravity idler is also installed to reduce the chance of melting out a bearing by overtightening the belt.

Roller Bearings

In the case of motors with ball bearings we have one expedient available which may save the day, at least in medium and small sizes of motors. Three makes of roller bearings are on the market, interchangeable in dimensions with standard ball bearings, which, within their speed limitations will carry about twice as much load as standard ball bearings of the same dimensions. These bearings will carry no thrust loads.

Where the speeds are not too high relative to the shaft diameter, that is, in medium and small sizes of motors, any reasonable increase in belt width is permissible when using these roller bearings in the pulley-end bearing and deep groove ball bearings in the front end to take the thrust. This permits belts 50 per cent wider than standard in almost all cases of 15 hp. or below and belts almost double standard width in small motors, particularly with the use of pivoted motor base or gravity idler.

Pivoted Motor Base and Gravity Idler

For short centers, combined with a considerable difference in pulley size, some special drive is almost a necessity.

A belt does all its work on the tight side but a considerable pull must always be on the slack side to make the belt grip the pulley and prevent slippage. With an ordinary belt drive, as the load comes on, the tight side stretches and passes extra length around into the slack side. Finally, as the load increases, the slack side may become so loose that the belt slips excessively. This is the extreme overload limit for the drive. To keep the capacity for occasional overload high, it is necessary to operate both slack side and tight side much tighter than is necessary to carry normal loads.

It is usual to tighten the belt for stretch more than necessary so that retightening will be avoided for some time. Both pivoted motor base and the gravity idler drive greatly reduce, in most cases, the pulls on both tight and slack sides of the belt, at all loads except extreme overloads, as they make it unnecessary to tighten the drive more than is needed for operating requirements. The motion of the pivoted base or the gravity idler takes up the stretch.

With a gravity idler or pivoted base properly adjusted, a motor may carry heavier intermittent loads than with an ordinary drive without overheating motor bearings, for the load on the motor bearings will be decreased during periods of light and normal load. During swings of abnormal load, the bearing pressures will approach those of an ordinary open drive but such periods are too brief to overheat the bearings. Similarly, belts last longer, if they are strained to carry extreme loads only during occasional swings of overload and run looser the remainder of the time.

On such a drive, properly adjusted, it is safe to use a belt slightly wider than could be used on the same motor with an ordinary drive. This is a lifesaver when pulleys smaller than standard are necessary on fairly high-speed motors. Note the words "properly adjusted" in the statement above. Some manufacturers of gravity idler drives send out a liberal supply of weights with the drive and leave it to the customer to determine the number and position of weights to be used. This will be fatal in a case where the motor bearings run very hot, unless the customer determines, on starting the job, the minimum weight required to carry the heaviest load fluctuations and uses no more.

As to the relative merits of the pivoted motor base drive and the gravity idler drive, the pivoted base drive is ordinarily supplied with a high-capacity, oak-tan belt, foreground, Fig. 2. For comparison consider the performance of the idler drive, background, Fig. 2, when operated with a similar belt.

Belt creep and slip within the capacity of the drive, are, for both the pivoted motor base drive and the gravity idler drive, so low as to be practically negligible, being normally less than 1 per cent.

The idler drive will carry somewhat more load with the same belt stress, motor bearing load and heating of motor bearings because, with the idler drive, the belt is ordinarily in contact with decidedly more than half the motor pulley surface while, with the pivoted base drive, the opposite is the case. Where the driven pulley is four times the diameter of the motor pulley and the center distance is short, or where the pulley diameter ratio is six with longer center distance, the gravity idler will carry decidedly more load than the pivoted motor base drive and is the drive to use, if maximum capacity is the determining factor. Where the pulleys are more nearly the same size, the idler drive shows less advantage in extreme capacity.

Where the pulley ratio is within reason and the maximum capacity from a given width of belt is not absolutely needed, the pivoted motor base drive has decided advantages. The gravity idler drive produces a severe reverse bend in the belt which greatly reduces belt life. It is much more severe treatment for a double belt to be reverse bent around a 6 or 8-in. roller as it leaves a 12-in. driving pulley, than to be run on a 6 or 8-in. driving pulley without reverse bending. The idler drive has the further disadvantage that on short center drives there is a considerable change, 30 to 50 per cent within the usual operating range of roller position, in slack side tension with moderate belt stretch. Since the exact roller position is a matter of the judgment of the operator and frequency of adjustment, some 20 to 30 per cent, allowance must be made in determining the idler weighting for a given peak capacity.

Efficiency of the gravity idler drive is slightly less than for the pivoted base drive, for there is some roller friction and roller windage; also a slightly longer belt is required, thus increasing belt windage losses. The

pivoted base adds no complications, nothing more to oil, to throw oil or grease, or to wear out.

If the above suggestions are followed such a thing as trouble with a flat leather motor-drive belt should seldom happen. Leather belt power transmission, when properly used, combines long life, low maintenance cost and dependability with a high sustained efficiency at average operating loads.

Secondary Electric Distribution Systems

SUCH DISTRIBUTION is usually at 550, 440 or 220 v. for three-phase currents, the lighting being single-phase on 115 or 230 v. at the substation. If lighting load is large, a 3-phase system with 3-wire circuits at 115 and 230 v. or with 4-wire circuits at 120 and 208 v. may give better balance of load on the phases.

For step-down of a.c. transmission voltage and for motor-generator transformation for d.c. supply, a substation should be located near the load center, the secondary system spreading from this, either in radial feeders, two sets in parallel, or as a loop, to give alternate methods of supplying current to each department.

Substation Layout

Equipment in the substation should include, besides the transformers and motor-generators, protection for incoming and outgoing feeders, instruments to indicate and record total and distributed load and switches which are able to handle such short circuit current as may arise. If automatic or semi-automatic operation is planned, circuit breakers should be electrically operated; for manual operation, their expense is seldom justified.

Transformers, single or polyphase depending on load, cost, and space requirements, should have capacity such that, if one fails, the load can be carried on those still in service. For usual capacities, the oil-immersed, self-cooling type is used, forced draft and water cooling being advisable only for large sizes. Protection involves temperature bell alarm, over-current and differential relays to operate oil-immersed circuit breakers.

Except for lighting, close voltage regulation is seldom necessary and where essential may be had by using automatic induction regulators. These may be in the primary or the secondary circuits but, if feeder lengths differ greatly, each feeder will need its individual regulator.

Where a motor is of size to interfere with voltage regulation on a feeder, it should have special connection to the primary system.

For switchboards, completely-assembled, steel-unit panels are generally better made and more economical than those built up locally. Standardized types of switches and instruments are mounted on panels ready to set in place and connect.

Location of transformers should be such as to make connection and replacement easy. For the air-blast type, setting over an air pressure chamber permits bringing connections through that chamber and automatic regulation of air pressure. For oil insulated transformers, provision for convenient replacement and purification of the oil should be made in designing the station layout.

Typical arrangement would be with primary switching on one side of the station, transformers and motor-generators in the center and distributing boards and control on the opposite side.

Good lighting, ventilation, fire prevention and grounding of equipment are essential. High-voltage switching and transformers may often be placed outdoors to good advantage.

Distribution Lines

Overhead lines are less expensive and usually preferred unless tunnels or ducts are to be provided for other services or the pole lines are objectionable. Poles, of height to give the desired clearance above ground and buildings are spaced 100 to 125 ft. apart. The butts up to 2 ft. above ground, or for yellow pine the whole pole should be impregnated with creosote; for locations where decay is particularly imminent, concrete bases may be desirable with iron clamps to support the poles.

Up to 5000 v., weatherproof insulated conductors are suitable, well separated to avoid contact and mounted on substantial cross arms and insulators. For taps, jumpers and locations where workers might contact the wires, extra insulation is desirable.

Wire should be of size to give mechanical strength as well as electrical conductivity, allowance being made for sleet loading.

Where lines enter buildings or connect to underground systems, lightning protection should be provided for carrying off electrostatic charges. Direct lightning stroke cannot be fully safeguarded but, where lightning is frequent, a ground wire above the conductors will lessen the danger.

For underground lines, ducts of impregnated wood, fiber, or tile, surrounded by concrete are used, depending on the permanence desired as against cost of construction. Concrete or brick manholes, of ample size for installation and maintenance of cables, should have eyebolts opposite duct ends for pulling in and racks on the sides for cable support. Good drainage and ventilation are important.

Cables with paper or varnished cambric insulation, covered with lead sheath are used or, for lower cost on lines up to 7500-v., rubber insulation, lapped tape, asbestos filler and sheath and covering of asbestos filler and braid saturated with fire and moisture resisting compound. More care is needed when installing the last mentioned to avoid injuring the protective covering.

For temporary use or frost-free locations, lead-covered cables may be laid in shallow trenches, or on the surface covered with stone or plank. It is well to have a steel armor outside the lead to prevent injury by stray rodents. Subway type transformers and cutouts with covers are then buried directly in the earth, the tops flush with grade.

BEST OPERATION of a combined hydro and steam electric system is generally by operating the hydro plant at the point of maximum efficiency during low-water periods and at maximum output for high-water. At low flow, hydro plants are held for instant use in emergencies due to steam plant shut down and water is stored for such use, the hydro capacity being otherwise used to largest available capacity consistent with keeping best load factor on the steam plants.—F. A. ALLMER, before International Electrical Congress.

Commercial Refrigerants and Their Properties

WIDE APPLICATION OF REFRIGERATION IN OVER 200 INDUSTRIES HAS LED TO DEVELOPMENT OF MANY REFRIGERANTS TO MEET NEEDS. BY WALLACE H. MARTIN*

SOMEWHAT OVER 200 different industries use refrigeration which is perhaps one of the reasons why the refrigerator industry is one of the most rapidly growing in this country. Nearly every branch of the food industry uses it and it is also found necessary in photography, printing, baking, textile manufacturing, air conditioning, and airplane manufacture, to mention only a few.

The ordinary refrigeration cycle is performed in three major pieces of equipment: the evaporator, the compressor and the condenser. In these three pieces of equipment a refrigerant of some kind is alternately liquefied and vaporized. For commercial plants, ammonia is almost universally used. For plants where safety in case of escape of refrigerant must be provided for, carbon dioxide is in use. With carbon dioxide the power requirements are greater than for any other refrigerant.

SULPHUR DIOXIDE

Next most commonly used refrigerant is sulphur dioxide. It is easy to obtain and fairly cheap. It has the advantage of being noninflammable since it is a product of combustion. At atmospheric pressure it boils at 14 deg. F. so in operation it is practically always under pressure and there is not much tendency for air to get into the system. It is necessary that moisture be kept out since H_2O with SO_2 forms H_2SO_3 (sulphurous acid) which causes rapid corrosion. Copper tubing and fittings are not as easily attacked as steel and are commonly used. It acts as a lubricant itself to a certain extent. The lubricating oil used should be free of water. It is its own irritant in case of leakage.

METHYL CHLORIDE

Methyl chloride, CH_3Cl is used in several machines. The pressures are somewhat higher than those obtained with sulphur dioxide. At atmospheric pressure it boils at 10 deg. F. below zero. It has no corrosive effect on metals. It is classed as inflammable but the range of mixtures which are explosive is rather narrow. In large quantities it acts like an anaesthetic. Some trouble was experienced in Chicago a few years ago. In a multiple unit system a leak developed and the occupants of an apartment were suffocated. It happened that methyl chloride was the refrigerant used. This circumstance led to some exhaustive tests by the Bureau of Mines.

Acrolien was mixed with methyl chloride in the proportions 0.9 per cent by volume of acrolien. It was found that the acrolien was thoroughly diffused through the methyl chloride, both liquid and gaseous. The results were: "Exposure to one part of acrolien vapor in a million parts of air produces marked irritation of the eyes and nose in five minutes or less. By using this as a criterion of the amount necessary to give warning, leakage from the units would be readily detectable when the methyl chloride concentration in air was 0.04 to 0.08 per cent by volume.

OTHER CHLORIDES

Ethyl chloride, C_2H_5Cl boils at atmospheric pressure at 55 deg. F. When used as a refrigerant it operates at a partial vacuum and there is a tendency for air to get into the system. Its other characteristics are much the same as methyl chloride except that it requires more displacement. It is not very generally used. One company uses three refrigerants, all chlorides: dichloroethylene (dieline, $C_2H_2Cl_2$); trichloroethylene (triline, C_2HCl_3); dichloromethane (carrene, CH_2Cl_2).

They all operate at pressures less than atmospheric on both high and low sides, require large displacements and lend themselves well to centrifugal compression.

HYDROCARBONS

Several hydrocarbons have been proposed as refrigerants. The principal objection to their use is their inflammability.

A new refrigerant was announced about 2 yr. ago. It is known as dichloro-difluoro-methane, CCl_2F_2 or commercially as F-12. It has many characteristics which make it very desirable as a refrigerant. The Bureau of Mines made an exhaustive series of tests in which guinea pigs, dogs and monkeys were exposed for 7 hr. a day for 60 da. in an atmosphere containing 20 per cent of the refrigerant.

The conclusion is stated in the Bureau report as follows: "Insofar as the results of animal experimentation serve as a measure of hazards to persons, the investigation described in this report has shown that the possibility of public health and accident hazards resulting from exposure to dichloro-difluoro-methane where used as a refrigerant are remote."

A comparison on the standard ton basis shows the discharge temperature of F-12 to be appreciably lower than that of other refrigerants. The power requirements are practically the same as for ammonia, sulphur dioxide, or methyl chloride, while the displacement is less than for any of these except ammonia. In all ordinary applications the pressure is greater than atmospheric.

SILICA GEL

Silica gel, or silicon oxide, has recently entered the refrigeration industry. In appearance it is like white sand. The size of the particles varies between 8 and 20 mesh and the percentage of voids is about 50. The particles are porous but the pores are so small as to be invisible even with the microscope. The result is an enormous surface area. It is used as an adsorbent in connection with SO_2 as the refrigerant. As the SO_2 vapor comes from the evaporator it is adsorbed by the silica gel. The process is primarily a surface concentration of the SO_2 on the silica gel particles and in the pores. The amount that can be adsorbed under normal operation is from 25 per cent to 35 per cent by weight.

*Professor of Heat Engineering, Oregon State Agricultural College, Corvallis, Ore. From a complete paper Recent Developments in Refrigeration presented before the Oregon Section of the A. S. M. E.

Cooperation Between Private Plants *and the* Utilities

Part IV

By
O. H. HENSCHEL Consulting Engineer Milwaukee, Wis.

CONTINUING OUR consideration of power costs in a furniture factory, we will now analyze the steam requirements for the plan involving full generation of electricity. From the previous article, it may be recalled that a turbine generating unit of 125-kv-a. rating was decided upon. From manufacturers' data it was found that with a unit of 125-kv-a. rating a water rate of 66 lb. per kw. hr. might be expected.

Accordingly, then, employing the 28-mo. period of average electric energy requirements, the average required monthly steam generation is easily figured. Taking the average required kilowatt consumption for each month, multiplying this figure by 66 lb. (the turbine water rate) and totaling the results, we find the total annual steam consumption to be 13,391,400 lb.

Knowing the cost of steam ($0.74 per 1000 lb.), the monthly and annual cost of this steam is also arrived at. In this case, the total cost for the steam for the year was found to be $9,908.74.

Equipment and Estimated Costs

In order to be ultra conservative in considering this phase of the problem and because of the fact that such units in excellent operating condition may be readily obtained at the present time, account was taken only of the cost of a good used generating set. Accordingly, then, the apparent estimated cost of equipment required for full electric energy generation was found to be

Housing	$2,000.00
(1) 125-kv-a., 220-v., 3-phase, 60-cycle tur. gen.	2,250.00
Switchboard and wiring	1,500.00
Piping, etc.	2,300.00
Total	$8,050.00

Except for lubricants, etc., the operating costs would prove to be practically nil, this primarily for the reason that one man should ordinarily be able to care for both boiler and turbine room equipment. We then could expect to have with full electric energy generation.

Operating charges	nil

Fixed Charges

Interest at 6 per cent	$ 483.00
Bldg. depreciation at 2 per cent	40.00
Equipment depreciation at 10 per cent	605.00
Taxes and insurance at 4 per cent	322.00
Total annual operating and fixed charges	$1,450.00

Summarizing, then, we find that under conditions specified and as apparently existing, attempting to generate all of the electric energy requirements would result in the following yearly costs.

Steam generation costs	$ 9,908.74
Operating and fixed charges in gen. equip.	1,450.00
	$11,358.74

This analysis, however, cannot be concluded at this point, for the following reason: During the winter or heating months, it appears that the exhaust from the generating units would prove to be not sufficient to meet heating and process demands. As a result, it would apparently become necessary to add considerable live steam to the heating system each winter.

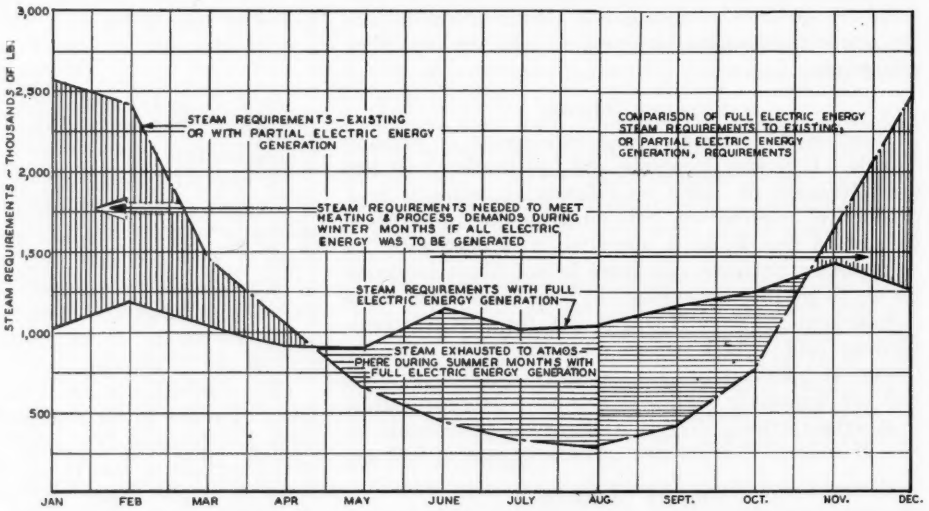


FIG. 1. COMPARISON OF FULL ELECTRIC ENERGY STEAM REQUIREMENTS TO EXISTING OR PARTIAL ELECTRIC ENERGY GENERATION REQUIREMENTS

Comparison reveals the following.

Month	Heating and Process Steam Requirements—thousands of pounds	Apparent Generating unit requirements—thousands of pounds	Apparent amount of steam required to be added to system during winter months—thousands of pounds
January	2,567.5	1,003.2	1,564.3
February	2,423.8	1,188.0	1,235.8
March	1,476.1	1,036.2	439.9
April	1,044.0	924.0	120.0
May	652.7	904.2	
June	451.2	1,148.4	
July	346.7	1,003.2	
August	289.7	1,056.0	
September	413.2	1,174.8	
October	769.9	1,247.4	
November	1,618.6	1,438.8	179.8
December	2,452.3	1,267.2	1,185.1
Total			4,724.9

It was evident, therefore, that with full electric energy generation an additional 4,724,900 lb. of live steam would have to be supplied to the heating system in addition to the exhaust. From a financial standpoint, this would result in an added cost of—

Month	Steam added to system—thousands of lb.	Cost of Steam added to system
January	1,564.3	$1,157.58
February	1,235.8	914.49
March	439.9	325.53
April	120.0	88.80
May		
June		
July		
August		
September		
October		
November	179.8	133.05
December	1,185.1	876.97
Total		$3,496.42

Obviously, then, with full electric energy generation the costs would be

Total apparent cost with full electric energy generation	$11,358.74	
	3,496.42	
		$14,855.16
Existing costs		15,498.34
Apparent annual gain to be expected by full electric energy generation		$ 643.18

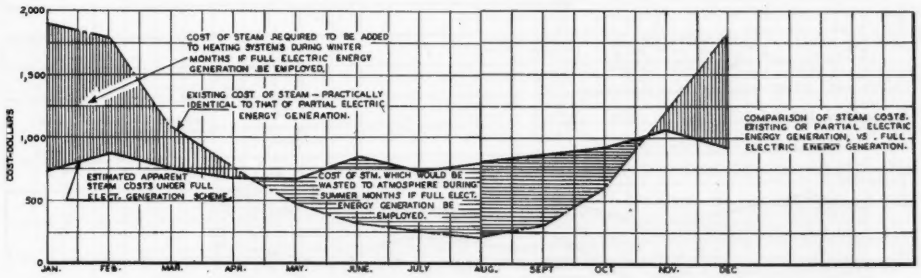
In Figs. 1 and 2 are shown charts illustrating the preceding discussion graphically.

Partial Electric Energy Generation and Its Probable Cost

A scheme being satisfactorily employed today to great advantage in many industrial plants is that of partial generation whereby a portion of the power requirements are purchased and the balance locally generated, the amount generated being dependent upon the demand for exhaust steam.

With such a scheme, the apparent estimated amount of steam available for electric energy generation and the apparent estimated amount of electric energy available for use would in the case under consideration appear to be as follows.

Month	Apparent steam requirements for heating and process	Apparent est. amt. steam available for electric energy generation	Apparent est. amount of electric energy available
January	2,567,546 lb.	621,835 lb.	9,421 kw-hr.
February	2,423,867 lb.	979,604 lb.	14,842 kw-hr.
March	1,476,123 lb.	676,620 lb.	10,252 kw-hr.
April	1,044,058 lb.	1,044,058 lb.	15,819 kw-hr.
May	652,662 lb.	652,662 lb.	9,880 kw-hr.
June	451,193 lb.	451,193 lb.	6,830 kw-hr.
July	346,706 lb.	346,706 lb.	5,250 kw-hr.
August	289,713 lb.	289,713 lb.	4,390 kw-hr.
September	413,197 lb.	413,197 lb.	6,260 kw-hr.
October	769,894 lb.	769,894 lb.	11,660 kw-hr.
November	1,618,605 lb.	819,102 lb.	12,410 kw-hr.
December	2,452,363 lb.	561,657 lb.	8,510 kw-hr.


2,000
1,500
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COST-DOLLARS
COST OF STEAM REQUIRED TO BE ADDED TO HEATING SYSTEMS DURING WINTER MONTHS IF FULL ELECTRIC ENERGY GENERATION BE EMPLOYED.
EXISTING COST OF STEAM — PRACTICALLY IDENTICAL TO THAT OF PARTIAL ELECTRIC ENERGY GENERATION.
ESTIMATED APPARENT STEAM COSTS UNDER FULL ELECT. GENERATION SCHEME.
COST OF STM. WHICH WOULD BE WASTED TO ATMOSPHERE DURING SUMMER MONTHS IF FULL ELECT. ENERGY GENERATION BE EMPLOYED.
COMPARISON OF STEAM COSTS. EXISTING OR PARTIAL ELECTRIC ENERGY GENERATION, VS. FULL ELECTRIC ENERGY GENERATION.
JAN.
FEB.
MAR.
APR.
MAY.
JUNE.
JULY
AUG.
SEPT
OCT
NOV.
DEC

FIG. 2. COMPARISON OF STEAM COSTS EXISTING OR PARTIAL ELECTRIC ENERGY GENERATION VS. FULL ELECTRIC ENERGY GENERATION

From the foregoing it is now possible to determine the amount of electric energy which would apparently be required to be purchased, in addition to that generated.

Month	Apparent amt. electric energy capable of being generated as above	Apparent amt. electric energy to be purchased under the partial generation scheme
January	9,421 kw-hr.	5,779 kw-hr.
February	14,842 kw-hr.	3,158 kw-hr.
March	10,252 kw-hr.	5,448 kw-hr.
April	14,000 kw-hr.	0,000 kw-hr.
May	9,880 kw-hr.	3,820 kw-hr.
June	6,830 kw-hr.	10,570 kw-hr.
July	5,250 kw-hr.	9,950 kw-hr.
August	4,390 kw-hr.	11,610 kw-hr.
September	6,260 kw-hr.	11,540 kw-hr.
October	11,660 kw-hr.	7,240 kw-hr.
November	12,410 kw-hr.	9,390 kw-hr.
December	8,510 kw-hr.	10,690 kw-hr.

This comparison is also presented graphically in Fig. 3.

Based upon the average existing cost of 2.3c per kw-hr., the cost of the electric energy required to be purchased in addition to that being generated was found to be $2,055.49.

Required Equipment and Its Cost

From preceding data, the expected average daily and hourly generation was found to be as follows.

Month	Av. daily amt. of electric energy to be generated—based on 26 working day mo.	Av. hourly amounts of electric energy to be generated, based on 8-hr. working day
January	323.9 kw-hr.	40.5 kw.
February	570.9 kw-hr.	71.3 kw.
March	394.3 kw-hr.	49.2 kw.
April		

May	380.0 kw-hr.	47.5 kw.
June	262.7 kw-hr.	32.8 kw.
July	201.9 kw-hr.	25.2 kw.
August	168.8 kw-hr.	21.1 kw.
September	240.7 kw-hr.	30.0 kw.
October	448.4 kw-hr.	56.0 kw.
November	477.9 kw-hr.	59.6 kw.
December	327.3 kw-hr.	40.9 kw.

This would thus indicate apparent hourly demands ranging from a minimum of 21.1 kw. to a maximum of 71.3 kw. But peaks must be provided for. Accordingly, then, we should tend to select a unit of, let us say, 62½ kv-a. rating.

Naturally, such a unit could well, at least momentarily, be made to carry 25 per cent overload and should such overload at any time prove to become in excess of 25 per cent of the unit's rating more energy might for the time being be drawn from the utility company's lines.

In order to determine fixed and operating charges, we may accept the following as an estimate of cost equipment required.

Housing	$2,000.00
(1) 62½ kv-a., 220-v., 3-phase, 60-cycle, turbo-gen.	1,350.00
Switchboard and wiring	1,250.00
Piping, etc.	1,800.00
Total	$6,400.00

As was the case in the presentation of the full generation scheme, the operating charges, except as for instance oils and waste, would prove to be practically nil. As a consequence, it was possible to enumerate

Operating charges ..... nil

Fixed charges

Interest at 6 per cent	$ 384.00
Bldg. depreciation at 2 per cent	40.00
Equipment depreciation at 10 per cent	440.00
Taxes and insurance at 4 per cent	256.00
Total annual operating and fixed charges	$1,120.00

Again summarizing to determine the apparent annual costs should the partial generation scheme be adopted, we may expect

Annual steam generating costs, apparently then would, or should remain practically as now existing $10,947.38

Apparent cost of electric energy required to be purchased 2,055.49

Fixed and operating charges on required equipment 1,120.00

Total apparent annual costs $14,122.87

With results of findings now on hand, it is possible to summarize.

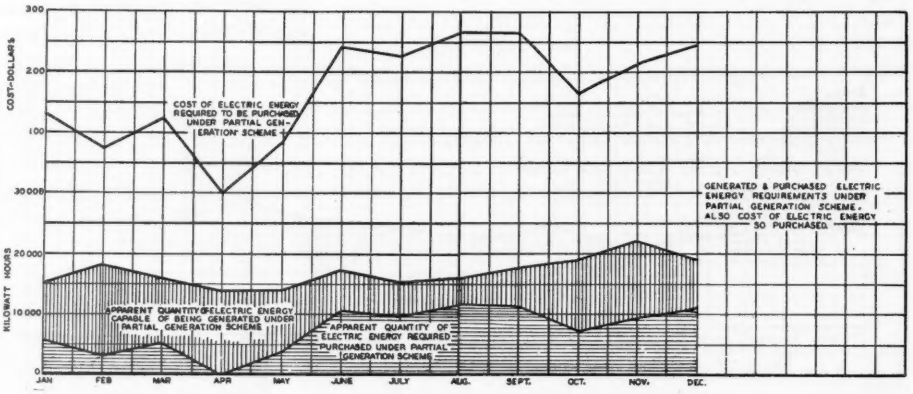


FIG. 3. GENERATED AND PURCHASED ELECTRIC ENERGY REQUIREMENTS UNDER PARTIAL GENERATION SCHEME. ALSO COST OF ELECTRIC ENERGY SO PURCHASED

Summary

(A) Annual existing combined steam and purchased electric energy costs amounting to $15,498.34

(B) To generate all electric energy requirements the apparent average annual costs would be 14,855.16

(C) While under the partial generation scheme apparent av. annual costs could be expected to be $14,122.87

Accordingly, then, interpretation reveals that

(1) If all electric energy requirements be generated apparent annual savings would amount to ..... $ 643.18

(2) Under the partial generation scheme apparent annual average savings would be $1,375.47

Obviously, then, there was found to be but one scheme advantageous to employ, namely that of generating an amount of electric energy which would result in the delivery of an amount of low-pressure steam consistent with space heating and process requirements.

All excess electric energy requirements, particularly during the non-heating months, are to be purchased from the local utility.

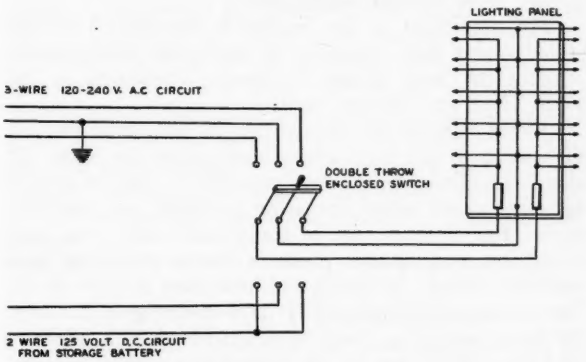
Editor's Note. This is the fourth and last of a series of articles on this subject by Mr. Henschel. The previous articles appeared in the Feb. 15, Mar. 15 and Apr. 15 issues respectively.

TESTS HAVE shown that the interconnection of the primary lightning arrester ground to the grounded neutral of the secondary main, on a pole type distribution transformer, effects a considerable reduction in voltages at the transformer and imposes no extra hazard upon the consumers' wiring.

Readers' Conference

Emergency Lighting in Power Plants

WHEN EMERGENCY lights are needed at a substation or power house, there should be no limitation to their availability. The accompanying sketch shows a method of wiring a double throw switch which allows switching all lighting circuits at a substation from a 3-wire a.c. source to the 125 v. d.c. station control battery.



METHOD USED TO PROVIDE EMERGENCY LIGHTING IN PLANT

This method of securing direct current lighting does not call for any duplicate lighting circuits, but when lights are needed for an emergency, they can be turned on exactly where needed.

Operators are instructed to limit their illuminating requirements to necessary lights only when using the battery for lighting.

Iron Mountain, Mich. L. W. WYSS.

Stresses in Pipe Bends

DETERMINATION OF STRESSES due to expansion in a right-angle bend is a simple matter with the use of the curves shown by Fig. 1. Knowing the total expansion of one of the elements, the reactions at the anchored end of this element are functions of its length.

To illustrate the use of these curves assume:

$a = 125$ in.
$b = 200$ in.
Coefficient of expansion = 1.96 in. per 100 ft.
Pipe size = 6 in. of 600 lb. S.S. tubing.
Modulus of elasticity, $E = 29 \times 10^6$ lb/sq.in.
Moment of inertia, $I = 37$ in.^{4}
Section modulus of pipe $w = 11.15$ in.^{3}

Then:

$b \div a = 200 \div 125 = 1.6$.

From curves:

$C_1 = 1.83$; $C_2 = 4.13$; $C_3 = 2.44$.

$dx = (125 \div 12) \times (1.96 \div 100) = 0.204$ in.

$dx\ E\ I = 0.204 \times 29 \times 10^6 \times 37 = 2189 \times 10^5$ lb. in.^{3}

$a^2 = 15{,}630$ in.^{2}

$a^3 = 1953 \times 10^3$ in.^{3}

$X = (3\ C_1\ dx\ E\ I) \div a^3 = (3 \times 1.83 \times 2189 \times 10^5) \div (1953 \times 10^3) = 617$ lb.

$Y = (3\ C_2\ dx\ E\ I) \div a^3 = (3 \times 4.13 \times 2189 \times 10^5 \div (1953 \times 10^3) = 1391$ lb.

$M = (-3\ C_3\ dx\ E\ I) \div a^2 = (-3 \times 2.44 \times 2189 \times 10^5) \div (15{,}630) = -102{,}400$ in. lb.

From this point, the moment diagram may be drawn and the stress determined at any point in the pipe line.

Proper construction of the moment diagram depends upon the accurate location of the neutral axis of the pipe line. The neutral axis is a plane along which no moments whatsoever exist, hence it passes through the so-called elastic center of the pipe line.

Referring to Fig. 2, the bend has been drawn to scale with the reaction forces drawn as vectors at the origin together with the resultant vector P = 1522 lb. The moment at any point in the pipe line is the algebraic sum of the moment of —102,400 in. lb. already determined for the origin and a moment induced by the

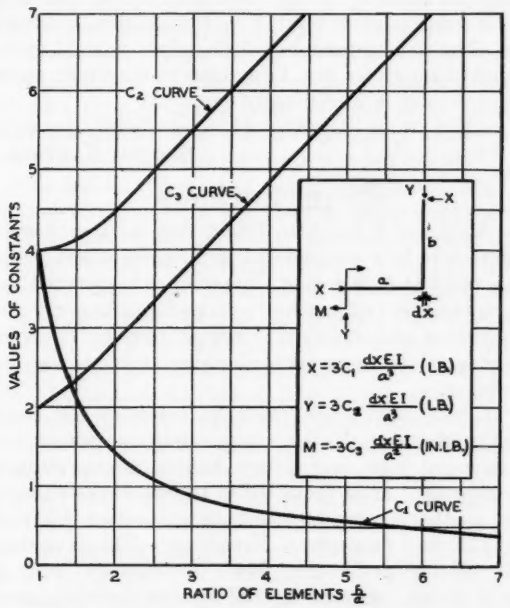


FIG. 1. REACTIONS IN RIGHT-ANGLE BENDS

resultant force P. The two act in opposite directions. The problem, then, is to determine the distance from the resultant force at which the force produces a bending moment of + 102,400 in. lb.

Thus: $+102{,}400 \div 1522 = +67.3$ in.

A line drawn at a distance of +67.3 in. from the resultant force and parallel to it will therefore accurately locate the neutral axis. If the distance AD is then designated as the moment at point A = —102,400 in. lb., then to the same scale the distance BE is the moment at point B and the distance CF is the moment of point C. Similarly the bending moment at any point in the pipe line may be scaled directly from the moment diagram.

If the problem is to determine the maximum stress in the pipe line due to expansion, the maximum bending moment is, of course used. This value divided by the

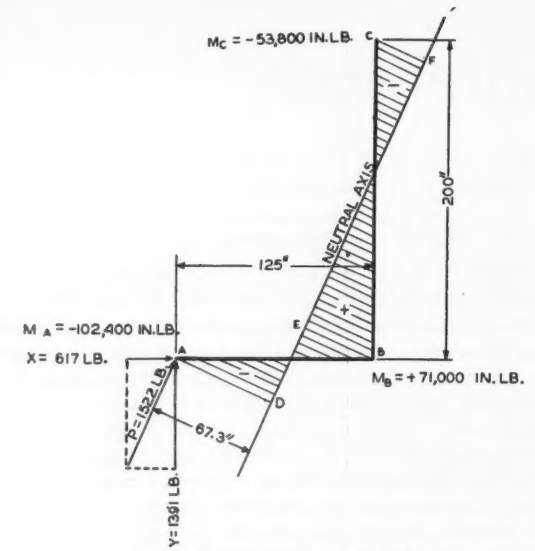


FIG. 2. MOMENT DIAGRAM

section modulus of the pipe section will give the maximum stress desired. Thus, from Fig. 2, the maximum bending moment is at point A and is equal to —102,400 in. lb. The section modulus of the pipe, w, is 11.15 in.^{3} The maximum stress due to expansion therefore occurs at point A and is numerically equal to:

$S = M \div w = 102{,}400 \div 11.15 = 9{,}184$ lb. per sq. in.

New York, N. Y. SAMUEL KAMEROS.

Steam Purifiers

IN ENGLAND it has been found that the use of steam purifiers is to be recommended in all cases where boilers are operated at high rating. Experience has proved that even on the best laid out and operated plants carry over of impurities and moisture is always possible. Purifiers are always to be recommended where steam is supplied to turbines.

Purifying the steam prior to reaching the superheater is advisable. Under severe conditions where purifiers have not been used, I have known turbine cleaning to be necessary after from six to twelve weeks running. After purifiers were installed an inspection after six months showed no deposit. Frequency of blowing down is not affected as blowing down is necessary from the point of boiler operation as well as from the clean steam point of view. Blowing down should be performed as usual.

Many forms of steam purifiers are provided with blow down drains and should be blown down and drained daily. The frequency of cleaning will depend on the condition of the steam. I have found the best way of cleaning to be to disconnect or shut off the steam main on either side, fill the purifier with a solution made in the proportions of one gallon water to one pound washing soda and then boil this by delivering a supply of steam to the water. After one hour of this treatment blow the water down, and then blow the purifier through with steam. This will remove any impurities or deposit.

The best way to determine the frequency of cleaning is to note the deposit removed at each cleaning and adjust the frequency of cleaning so as to permit the accumulation of only a small amount of sludge and deposit.

Herts, Eng. W. E. WARNER.

Boilers Should Be Tested Under Actual Working Stresses

SOMETHING LIKE 20 yr. ago, in an engineering journal that was well known at that time, I predicted that engineers would some day operate "rivetless boilers". A critic in one of the following issues of the same journal ridiculed the idea. He as much as said that I should have my head examined—that rivetless boilers were totally impracticable.

Of course every engineer now knows that the rivetless boiler has been with us for some time, so I am feeling better. I am, however, not content with resting on the laurels of that successful prediction—I hereby make another, as follows:

My prediction is that boilers in the future will be tested under high pressure, at operating temperature, without the least danger to human attendants in the event of an explosion or rupture.

Every engineer knows that the old cold water method of testing is not satisfactory and never has been. It should be eliminated as soon as possible. Boilers should be tested under actual operating pressures and temperatures. For instance, not so many years ago I was sent to witness some tests on pressure vessels which had been entirely welded. No rivets had been used in them at all. The vessels were about 3½ ft. in diameter by 30 ft. long. In actual operation, they were subjected to a pressure of about 200 lb. per sq. in. alternating with a vacuum. When under pressure, the vessels were hot and when under vacuum they were cool.

To perform the tests, these vessels were filled with ordinary cold water out of the water mains which was pumped into them until a pressure of about 500 lb. per sq. in. was reached. There was no leakage. Then a strong young man was told to do some pounding with a sledge hammer here and there on the vessel. This pounding probably was supposed to duplicate the effect of heat. The man didn't strike very hard but he did make considerable noise. The vessels didn't leak. Upon completion, the tests were pronounced "successful".

I must say that, to me, the performance bore a semblance of child's play and I said so, but I was assured by this manufacturer that all pressure vessels which they made were tested in this way and that everybody else tested them in this same way. So far as I know, according to "specifications" which I see now and then, they are still being tested in the same old orthodox way. In other words, "the method was good enough for grandfather and so it's still good enough for me."

Having done considerable consulting work for a concern that manufactures salts for heat treating purposes, I have a suggestion to make in this connection which I believe is constructive and practicable, to wit: instead of using cold water, use a *hot* salt solution. Use a salt which has a melting point slightly lower than the temperature under which the test should be made. As will be verified by any heat treating expert, we now have many commercial salts on the market which have various melting points. By filling the pressure vessel with the proper liquefied salt at a temperature of 500 deg., 600 deg., 700 deg., 800 deg. or any other desired temperature, there would be no violent explosion in the event of a serious leak. There would be no explosion at all. The pressure and temperature of any boiler

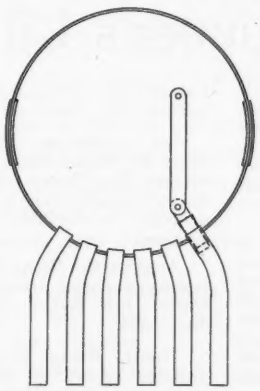
could be duplicated perfectly under tests like these. In fact, the test pressure and temperature could both be higher than working temperature and pressure and even then there would not be the slightest danger involved. There would be no formation of gas or steam. The only possible objection I can think of would be the greater cost of the test solution. This expense, however, would be no great burden to a manufacturer of boilers as he could use the same solution over and over. It would not spoil. There would be little loss or waste year after year.

Going back to the improper cold method of testing, let me add that one of the vessels tested as described above didn't last long in actual service. One of the seams opened and a bad ammonia leak resulted. There was no explosion but, anyway, it was soon decided by the owner to change over to another system and abandon the dangerous welded tanks. So you see rivetless pressure vessels do have their weak moments even after cold tests in which the testing pressure is more than twice the operating pressure. My contention is that it is extremely important that boilers be properly tested under correct temperature conditions as well as pressure conditions.

Newark, N. J. W. F. SCHAPHORST.

Cleaning Bent Tube Boilers

IT IS GENERALLY accepted that it requires two men to operate one tube cleaner in bent tube boilers, one man inside of the drum directing the cleaner, another on the outside operating the air valve. For a number of years I



SUPPORT FOR EXTENSION ROD

have been operating tube cleaners in such boilers with one man per cleaner, in the following manner:

A ¾-in. air line is run along each side of the boiler, with outlets near the man holes of each drum in which a cleaner must operate. These outlets are blanked when not in use. A ¾-in. quick opening lever type throttle valve is placed on this outlet. A ½-in. hole is drilled in the end of the lever, the valve being so located that the lever is directly in front of the man hole opening and can be operated by a rod through the manhole opening. This extension rod consists of a length of ¼-in. pipe with a hook welded in one end. The hook fits in the ½-in. hole in the end of the throttle lever. The ¼-in. pipe extends inside of the drum for ½ of its length. A similar rig is placed on the opposite end of the drum, so that two cleaners can operate in a drum at the same time.

The extension rod is supported inside of the drum by one or more supports as shown in the sketch. The support consists of a tapered wooden plug about 7 in. long, fitting a tube end snugly when driven up half its length. The plug is then split through the center from end to end and ⅛ in. of material removed from each half. A piece of ¼ in. flat iron about 9 in. long and slightly less in width than the inside tube diameter is wedged in place in a tube end by the two halves of the wooden plug. A second piece of flat iron ¼ x 1½ in. with guide holes for the ¼ in. pipe is bolted to the end of the first piece. This is adjusted to a convenient position and made tight.

This system works satisfactorily, and actually takes one-half as much time as operating a tube cleaner with the older method.

Baltimore, Md. J. R. GRAVES.

Boiler Furnaces

RECENT installations all tend toward one purpose, to secure as near complete combustion as possible before gases contact with the heating surfaces. Increased volume permits burning high-volatile, low-priced coals at high temperature with little smoke and low gas velocity carries little fine coal up among the tubes.

Where study shows room for improvement the cost of rebuilding a setting will vary, of course, with the size and type of installation but, for large power or small industrial boiler, cost of the changes will be repaid many times in savings due to improved results.

The ignition arch is of more importance than often realized. It should be designed to cause combustion in a high temperature zone over the fuel bed and throat opening should be narrower than is usual practice in furnaces. Too large a throat allows insufficient turbulence so that volatiles pass up through the tubes at the front and air streams at the rear of the stoker, without mixing. Too narrow a throat, however, gives a choking effect, blanketing the fire so that high output is impossible and life of the refractories is shortened.

Tests have shown most satisfactory results with a throat opening of 25 to 35 in. for chain grate stokers with vertical baffling. Height of the arch above the grate will vary with type of installation and grade of coal but averages 13 to 18 in., the arch ending so that the throat is over the hottest part of the fire to expose the lowest boiler tubes to the radiant heat from that point.

Type of firebrick used has much to do with maintenance cost. One method that has given excellent results with stokers operated at high output was carborundum brick on each side wall from just below the fire line to 24 in. above it, the rest of the furnace lining being a good grade of fire clay brick. After over 2 yr. operation on a 300-hp. boiler furnace maintenance has been negligible, with practically no slag formation, burning coal of 16 to 18 per cent volatile and 5 per cent ash smokelessly.

West Roxbury, Mass. HARRY M. SPRING.

FOR HEATING SYSTEMS, dividing the B.t.u. per hour needed by 1000 will give nearly enough the pounds of steam required per hour. Cast-iron radiation will condense 1 lb. of steam per hour for each 4 sq. ft. and pipe coils will condense 1 lb. per hour for each 3 sq. ft.

News From the Field

SUPREME OFFICERS elected at the annual convention of American Order of Steam Engineers are: Chief Engineer, Richard George of Philadelphia; First Engineer, William C. Simmons, Southwark; Recording Engineer, William Farney, Copley; Corresponding Engineer, Harry Singley, Atlantic City; Treasurer, Lewis Schlehner, Germantown; Master Mechanic, Edwin Colin, Camden; Junior Master Mechanic, William Zeller, Southwark; Chaplain, Warren Morris, Atlantic City; Outside Sentinels, John I. Rutherford, Atlantic City and S. Souder, Germantown; Trustee, Richard Sinnott, Camden.

IOWA state association, N. A. P. E. has elected officers as follows: President, R. E. Tunwall, Davenport; Vice-president, R. U. Marsh, Waterloo; Secretary, Lee Mason, Waterloo; Treasurer, Charles Amos, Sioux City; Conductor, Frank Parks, Davenport; Doorkeeper, R. A. Watts, Ottumwa; State Deputy, W. A. Bike, Marshalltown. Davenport will be the convention city for 1933. Papers were read by Dr. O. R. Sweeney, Royal Holbrook, J. L. Harrington, J. H. Drabelle and H. A. Stade.

AT RIVERSIDE, N. J., the Zurbrugg Memorial Hospital recently installed two 60-hp. steel heating boilers fired by 2 by 6 ft. Whiting stokers. During an acceptance test, with stokers running at maximum rating, efficiency of approximately 70 per cent was obtained. The stokers burn No. 3 Anthracite buckwheat which sells in that locality for approximately $3.00 a ton. The installation uses a full reverse arch connecting with the bridge wall at the rear and extending upward toward the front at a slight angle, reaching a point only 16 in. from the front wall of the furnace. There is a small curved arch at the extreme front which serves to terminate the front wall of the furnace. With Bituminous coal this front arch has ignition properties but with anthracite coal the reverse arch is depended upon for this effect.

Automatic pressure control is used with a banking switch on the stoker designed to operate the stoker five minutes out of every half hour. The architect was Morris & Erskine, Philadelphia; the plumbing and heating contractor, the Mechanical Equipment Co. of Philadelphia. Joseph Harrington of the Whiting Corp. designed and installed the stokers.

MILLIKEN VALVE Co. announces a new 7-part, plug-type valve with "nicrofer" parts.

H. P. CHARLESWORTH, vice-president, Bell Telephone Laboratories, Inc., New York, N. Y., was elected president of the American Institute of Electrical Engineers for the year beginning August 1, 1932, as announced at the annual meeting of the Institute held in Cleveland, Ohio, during the summer convention of the Institute. The other officers elected were—Vice-Presidents: J. Allen Johnson, Buffalo, N. Y.; E. B. Meyer, Newark, N. J.; K. A. Auty, Chicago, Ill.; G. A. Mills, Dallas, Tex.; C. R. Higson, Salt Lake City, Utah. Directors: G. A. Kositzky, Cleveland, Ohio; A. H. Lovell, Ann Arbor, Mich.; A. C. Stevens, Schenectady, N. Y. National Treasurer, W. I. Slichter, New York, N. Y. (reelected).

These officers, together with the following hold-over officers, will constitute the Board of Directors for the next administrative year, beginning August 1: C. E. Skinner (retiring president), East Pittsburgh, Pa.; W. S. Lee, Charlotte, N. C.; W. B. Kouwenhoven, Baltimore, Md.; W. E. Freeman, Lexington, Ky.; P. H. Patton, Omaha, Neb.; A. W. Copley, San Francisco, Calif.; L. B. Chubbuck, Hamilton, Ont.; J. E. Kearns, Chicago, Ill.; F. W. Peek, Jr., Pittsfield, Mass., C. E. Stephens, New York, N. Y.; A. B. Cooper, Toronto, Ont.; A. E. Knowlton, New York, N. Y.; R. H. Tapscott, New York, N. Y.; L. W. Chubb, East Pittsburgh, Pa.; B. D. Hull, Dallas, Texas; H. R. Woodrow, Brooklvn, N. Y.

The annual report of the Board of Directors, presented at the meeting, showed a total membership on April 30, 1932, of 17,550 In addition to three national conventions and two District meetings, 1632 meetings were held during the year by the local organizations of the Institute in the principal cities and educational institutions in the United States, Canada, and Mexico.

JOHN B. ALLINGTON, who for 15 yr. was in charge of the gas heating and industrial gas department of the Rochester Gas & Electric Corp., has been appointed director of the gas equipment and gas air conditioning division of the Petroleum Heat and Power Co. with headquarters at Stamford, Conn. Mr. Allington is now developing a new line of air conditioning furnaces for either oil or gas fuel.

MASON REGULATOR Co. of Boston, Mass., announces the opening of a new office in Chicago at 1525 East 53rd St., in charge of William P. Gearon who has represented the company in Chicago for the past five years. This office will also be occupied by the Neilan Co., Ltd. (a Division of the Mason Regulator Co.), the representative being Arthur J. Foley.

H. M. OLSON, formerly district sales manager of The Permutit Co., also formerly with the Kennicott Co., is now special representative for the Ohio Salt Co., Wadsworth, Ohio, handling salt for water softening purposes, Home Office—171 Longue Vue Drive, Pittsburgh, Pa.

ANNOUNCEMENT is made that 293 manufacturers of power producing machinery, power transmission equipment, control and measuring instruments, material-handling equipment and heavy electrical machinery will exhibit at the Grand Central Palace, New York, from Dec. 5 to 10. During the 2 yr. since the last exposition, much research has been carried on and the results will be shown in the form of improved machinery and economies. Arrangements are in charge of International Exposition Co., Grand Central Palace, N. Y.

For the Engineer's Library

FLOW OF AIR Through Circular Orifices in Thin Plates by J. A. Polson and J. G. Lowther, published as Bulletin 240 by the Engineering Experiment Station, University of Illinois, Urbana, Ill. Size 6 by 9 in. paper, 37 pages, price $0.25. (A limited number available for free distribution.)

Continuation of the work published in bulletin 207, carrying the investigation from the circular orifice with rounded approach to the square edged circular orifice in thin plates. Among the conclusions were:—Coeffiecients of discharge through square-edged orifices in thin plates increase in value with an increase in inlet pressure up to the critical pressure, when the coefficient is based on Dueley's equations; square-edged orifices should be very carefully used and preserved, slight injury to the entrance edge may cause a change in the coefficient of from two to three per cent, which may not be detected until the orifice is recalibrated.

FITTINGS FOR Raw Water Ice-Making Systems as made by Frick Co., Waynesboro, Pa., are shown in detail, including drop tubes, air fittings, air agitating systems, thawing needles, core suckers and refillers brine-testing sets and the like in Bulletin No. 128-A. A special feature is cooling fins for attachment to pipe in room coils, giving increased cooling capacity without shutting down the system or adding new coils. The bulletin gives net prices, also photographs and symbol numbers needed for ordering the parts.

COMBINED water scrubber and silencer in a single non-corrodable unit is described in a circular issued by the Maxim Silencer Co., Hartford, Conn.

JET CONDENSERS and auxiliaries as made by Pennsylvania Pump and Compressor Co., Easton, Pa., and marketed by Byer Engineering Co., New York, are described in Bulletin No. 411 recently received.

ALEXANDER BROS., Philadelphia, are issuing a power transmission guide for leather belt drives, known as Catalog No. A-103.

HIGHER STEAM Pressures and Temperatures report by the Prime Movers Committee of the National Electric Light Ass'n issued as Publication No. 220 compares performance records from five 600 lb., three 1200 lb. superimposed and three straight 1200 lb. stations. The bulletin also includes availability and use records for twenty-two 1200 lb. boilers and discussions of the 1000/3500 lb. experimental boiler and the 1200 lb. 825/850 deg. cycle. The bulletin also contains a discussion of fusion welded boiler drums and properties of ferrous metals at elevated temperatures.

NORTHERN EQUIPMENT Co., Erie, Pa., describes in Folder 127 the new Copes D A regulator for locomotives and horizontal tubular boilers, also in Folder 129 the type S D S governor to control excess pressure in boiler feed-water lines.

TYPE A inverted bucket trap made by the Swartwout Co., 18511 Euclid Ave., Cleveland, Ohio, is described and illustrated in its bulletin S-11, showing details and the multiple lever mechanism for developing large capacity.